[H.A.S.C. No. 113–96]

HEARING

ON

NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2015

AND

OVERSIGHT OF PREVIOUSLY AUTHORIZED PROGRAMS

BEFORE THE

COMMITTEE ON ARMED SERVICES
HOUSE OF REPRESENTATIVES

ONE HUNDRED THIRTEENTH CONGRESS

SECOND SESSION

SUBCOMMITTEE ON INTELLIGENCE, EMERGING THREATS AND CAPABILITIES HEARING

ON

DEPARTMENT OF DEFENSE FISCAL YEAR 2015 SCIENCE AND TECHNOLOGY PROGRAMS: PURSUING TECHNOLOGY SUPERIORITY IN A CHANGING SECURITY ENVIRONMENT

HEARING HELD
MARCH 26, 2014

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DEPARTMENT OF DEFENSE FISCAL YEAR 2015 SCIENCE AND TECHNOLOGY PROGRAMS: PURSUING TECHNOLOGY SUPERIORITY IN A CHANGING SECURITY ENVIRONMENT

HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SUBCOMMITTEE ON INTELLIGENCE, EMERGING
THREATS AND CAPABILITIES,
Washington, DC, Wednesday, March 26, 2014.

The subcommittee met, pursuant to call, at 2:52 p.m., in room 2212, Rayburn House Office Building, Hon. Mac Thornberry (chairman of the subcommittee) presiding.

OPENING STATEMENT OF HON. MAC THORNBERRY, A REPRESENTATIVE FROM TEXAS, CHAIRMAN, SUBCOMMITTEE ON INTELLIGENCE, EMERGING THREATS AND CAPABILITIES

Mr. THORNBERRY. The hearing will come to order. Thank you all for your patience. It is inevitable that whenever this subcommittee has a hearing scheduled,that is when votes will be on the floor. It happens every single time. But I do appreciate y'all bearing with us. We will have votes again in roughly an hour and a half or so, so we will need to move as expeditiously as we can. And with that in mind, I am going to forego any opening statement.

Yield to the distinguished gentleman from Rhode Island for any comments he would like to make.

STATEMENT OF HON. JAMES R. LANGEVIN, A REPRESENTATIVE FROM RHODE ISLAND, RANKING MEMBER, SUBCOMMITTEE ON INTELLIGENCE, EMERGING THREATS AND CAPABILITIES

Mr. LANGEVIN. Thank you, Mr. Chairman. I just want to welcome our witnesses here today. And given the time concerns, I will follow your lead, Mr. Chairman. I will forego my opening statement.

I will submit it for the record.

Mr. THORNBERRY. I thank the gentleman. And without objection, all of your written statements will be made part of the record, and you will all have a chance to summarize your comments, if you don't mind.

And, Mr. Shaffer, please lead off.

STATEMENT OF ALAN R. SHAFFER, ACTING ASSISTANT SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING, DEPARTMENT OF DEFENSE

Mr. SHAFFER. Well, you know, it is always wonderful being the chief technology officer of the Department and not knowing how to operate these things.

[Laughter.]

Mr. SHAFFER. Chairman Thornberry, Ranking Member Langevin, members of the committee, I am pleased to come before you today to testify about the fiscal year 2015 Department of Defense [DOD] science and technology [S&T] program. I am also proud to be here to represent the 100,000 scientists and engineers in the Department, a workforce that has had remarkable achievements in the past, but is now a workforce showing the early stages of stress.

The collective impact of the 2013 civilian furlough and program curtailment, the October 2013 government shutdown, and the indirect impacts of the sequester—such as restrictions on our young scientists and engineers attending technical conferences and reductions in hiring new scientists and engineers—has impacted the health of our workforce and the programs they execute in ways that we are just beginning to understand.

We have begun to address these challenges and know we will defeat them, but they do remain a concern. The fiscal year 2015 budget request for science and technology is relatively stable. The DOD S&T request is $11.5 billion, compared to a 2014 appropriation of $12 billion. The request represents a 4 percent decrease in the Department's S&T program compared to a flat RDT&E [research, development, test and evaluation] budget request.

While we continue to execute a balanced program, there are factors that led Secretary Hagel to conclude, in his February 24 fiscal year 2015 budget rollout, that the development and proliferation of more advanced military technologies by other nations means that we are entering an era where American dominance on the seas, in the skies, and in space can no longer be taken for granted. The Department is in the third year of a protracted and rapid top-line and RDT&E budget drawdown.

As highlighted by the Secretary, there are three major areas that compromise the Department's budget: force size, readiness, and modernization. The current budget is driving a force-size reduction, but this reduction will take several years to yield significant savings. In the fiscal year 2015 budget, readiness and/or modernization will pay a larger percentage of this reduction bill. Our technological superiority is challenged by increasingly sophisticated military capabilities rapidly emerging around the globe.

Within a fiscally constrained environment, our modernization efforts are focused on the enablers that keep our military equipment technologically superior to the emerging threat. Accordingly, we developed a strategy for the research and engineering program whereby we invest in research and engineering for three reasons. The first is to mitigate new and emerging threat capabilities. We see significant need in electronic warfare, cyber activities, counter-weapons of mass destruction, and preserving space capabilities in a contested space environment.

The second is to affordably enable new or extended capabilities in existing and new military platforms. We see significant need for systems engineers, modeling and simulation, and an expansion in prototyping efforts across the Department. The third reason we invest in research and engineering is to develop technology surprise. We see significant opportunities to advance our technologies in autonomy, human systems, quantum sensing, and big data. We have a balanced program that is yielding significant innovation across the DOD. DARPA [Defense Advanced Research Projects Agency] continues to deliver new capabilities that will allow the DOD to stay technologically advanced, and Dr. Prabhakar will detail some of these programs.

But we are also seeing groundbreaking capability developments in the services and agencies. Whether it is the first operational deployment of a laser system on the USS *Ponce* or the development of the future helicopter in the Army's joint multi-role helicopter demonstration, or the first-ever demonstration of an air-breathing hypersonic system such as accomplished by the Air Force's X–51 missile last year, the Department's S&T program continues to deliver.

The last year has been challenging to the Department's S&T program. The risk to our force is growing, and the need for the science and technology community, and delivery, is likewise increasing. While the challenges are increasing, the Department as a whole recognizes the need to maintain technological superiority as a cornerstone of the future force. We still have the best military, defense industrial base, and laboratory and university research systems.

However, instability and effects of the Budget Control Act and the near-term lack of balance between force structure, readiness, and modernization will increase the risk to our future force.

Thank you, sir.

[The prepared statement of Mr. Shaffer can be found in the Appendix on page 31.]

Mr. THORNBERRY. Thank you.

Ms. Miller.

STATEMENT OF MARY J. MILLER, DEPUTY ASSISTANT SECRETARY OF THE ARMY FOR RESEARCH AND TECHNOLOGY, U.S. ARMY

Ms. MILLER. Chairman Thornberry, Ranking Member Langevin, and distinguished members of the subcommittee, thank you for this opportunity to discuss the Army's science and technology program for fiscal year 2015. After 13 years of persistent conflict, the United States finds itself in a familiar situation, facing a declining defense budget and a strategic landscape that continues to evolve. Given the budget downturn within the Department of Defense, the Army has been compelled to face some difficult choices.

As Mr. Shaffer noted, we must balance between force structure, operational readiness, and modernization to maintain a capable force able to prevent, shape, and win any engagement. The Army will adapt, remaining an ever-present land force unparalleled throughout the world. As a result of these difficult budget decisions, however, we face a situation where modernization will be slowed over the next 5 years. New programs will not be initiated

as originally envisioned, and the Army's science and technology enterprise will be challenged to better prepare for the programs and capabilities of the future.

There is an old saying that my boss, Ms. Shyu, the Army acquisition executive, likes to use when explaining the Army's modernization strategy. "The best time to plant a tree was 20 years ago. The second-best time is today." And as we draw down forces from Afghanistan, today is the best time to plant seeds for the Army of the future. This is not a new concept. At the end of all major conflicts, we begin to focus on preparing for what is next.

Perhaps the most successful example of planting future seeds is found at the end of the Vietnam conflict, where the Army focused on developing the big five—Abrams, Bradley, Black Hawk, Apache, and Patriot—platforms that still dominate the fight today. It is this mindset that led the Army leadership to protect our S&T investment, their seed corn for the future. Despite these great budget challenges, much trust has been placed in our Army S&T community.

When I testified to this committee last year, I spoke about an initiative to generate a comprehensive modernization strategy that would facilitate informed strategic decisions, based on long-term objectives, within a resource-constrained environment. I am happy to report that this new process has been extremely beneficial for the Army, and is a process we have continued. The long-term look over the next 30 years was exceptionally powerful in facilitating the strategic decisions made within the Army as we built the fiscal year 2015 President's budget.

It allowed the Army leadership to make tough program decisions based on providing the most capability to our soldiers, knowing that in some cases that meant delaying desired capabilities. Last year, I also discussed the need for flexibility to balance across our investment portfolios. For fiscal year 2015, we were allowed to do this. It made a critical difference in the Army strategy, allowing us to make a deliberate increase in our advance technology demonstration funding—budget activity three—from previous years.

This is essential as the Army looks to its S&T community to conduct more technology demonstration and prototyping initiatives that will focus on maturing technology, reducing program risk, defining realistic requirements, and conducting experimentation with soldiers to both refine new capabilities and develop new operational concepts. The S&T community will be challenged to bring forward not only new capabilities, but capabilities that are affordable for the Army of the future.

You will see that the Army S&T portfolio is increasing emphasis on research areas that support the next generation of combat vehicles; A2/AD [anti-access/area denial] technologies, such as Assured Position, Navigation, and Timing; soldier selection tools and training technologies; and long-range fires. We are also increasing vulnerability assessment investments, red-teaming our technologies, our systems, and systems of systems to identify potential vulnerabilities, including performance degradation in contested environments, interoperability, adaptability, and training in ease of use.

None of this would be possible without the world-class cadre of over 12,000 scientists and engineers that make up the Army

science and technology enterprise. Despite this current environment of unease within the government civilian workforce—exacerbated over this past year—we continue to have an exceptional workforce. They are up to the challenge that the Army has given to them.

This is an interesting, yet challenging, time to be in the Army. Despite this, we remain an Army that is looking towards the future while taking care of our soldiers today. I hope that we can continue to count on your support as we move forward.

Thank you again for all that you do for our soldiers.

[The prepared statement of Ms. Miller can be found in the Appendix on page 55.]

Mr. THORNBERRY. Thank you.

Admiral.

STATEMENT OF RADM MATTHEW L. KLUNDER, USN, CHIEF OF NAVAL RESEARCH, U.S. NAVY

Admiral KLUNDER. Chairman Thornberry, Ranking Member Langevin, subcommittee members, it is an honor to be here today to report on science and technology efforts in the Department of the Navy and discuss how the President's 2015 budget request supports the Navy and Marine Corps.

We use science and technology to enable our Navy and Marine Corps team to maintain the technological edge necessary to prevail in any environment where we are called to defend U.S. interests. We work with the Secretary of the Navy, the Chief of Naval Operations [CNO], and the Commandant of the Marine Corps to balance the allocation of resources between near-term innovation and long-term leap-ahead research.

Our goal is to improve our warfighting capability to counter increasingly complex threats in this uncertain environment, while at the same time addressing affordability in a serious way with our systems. Beginning with the evolution of current systems, through incremental, spiral development of current technology, we move toward exploiting yet-to-be-discovered, disruptive, game-changing technologies. The Naval S&T Strategic Plan guides our investments and is regularly updated by Navy and Marine Corps leadership to validate alignment of S&T with current and future missions, priorities, and requirements, and ensures that S&T has long-term focus, meets near-term objectives, and makes what we do clear to decisionmakers, partners, customers, and performers.

The S&T plan that I just referred to is currently under review and will be updated in the very near future. We fully understand that anti-access/area denial threats continue to increase. Cyberwar challenges will also increase and become more complex. These problems are not easy to solve, but we are making progress. And as I said last year, we want to get away from using $3 million weapons to defeat $50,000 threats.

We have weapons in development and being fielded here currently that will allow us to reverse that asymmetrical cost advantage currently held by some of our adversaries. These are not pie-in-the-sky science projects. These are being tested, they work. I invite you and your staffs to get hands-on experience and see them for yourselves. I know some of you have been down there already,

but certainly at the Naval Surface Warfare Center at Dahlgren, the Naval Research Laboratory [NRL] here in Anacostia, where our world-class scientists and civilian employees are making those things happen.

The bottom line is, we are constantly transitioning the results of Discovery and Invention applied research into fielding prototype weapons, and acquisition programs of record. We were commended for the way we do it by the 2013 Government Accountability Office report cited in my testimony. But it is not enough to build and transition effective systems. We need to be extremely affordable.

An ongoing example of our success is the Laser Weapon System, part of our solid state laser maturation effort. We feel energy weapons, specifically directed energy weapons, offer the Navy and the Marine Corps game-changing capabilities in speed-of-light engagement, deep magazines, multi-mission functionality, and affordable solutions. Laser weapons are very low engagement costs—right now, we are literally under a U.S. dollar per pulsed energy round—which is critical in our current fiscal environment.

They are capable in defeating adversarial threats, including fast boats, UAVs [unmanned aerial vehicles] and other low-cost, widely available weapons. Now, our Laser Weapon System—again, referred to as LaWS—leverages advances in commercial technology for use in a rugged, robust prototype weapon capable of identifying, illuminating, tracking, and lasing enemy surface and air threats. The Navy is installing this LaWS system on board the USS *Ponce* in the Arabian Gulf this year; this summer, to be exact.

That harsh and operationally important environment will provide an ideal opportunity to evaluate long-term system performance. We believe that LaWS has every potential for extraordinary success in field—terms of fielding an effective, affordable weapon for our sailors and Marines.

An electromagnetic railgun is also similarly poised to provide game-changing disruptive capability for our long-range attack ballistic missile, cruise missile defense in anti-surface warfare against ships and small boats.

Fired by electric pulse, railgun has the potential to launch projectiles over 110 nautical miles. With this projectile development underway, and barrel life on a path to 1,000 shots, we feel very strong about this capability. Current research is focused on a rep rate, repetition rate, capability of multiple rounds per minute, which entails development of a tactical prototype barrel and pulse power system incorporating advanced cooling techniques. Developmental tests right now are ongoing at Naval Surface Warfare Center Dahlgren and at NRL, along with evaluation and integration of new and existing naval platforms.

And this might be new news, but the railgun testing, we are going to do that on board a JHSV, Joint High Speed Vessel, in 2016. We will continue to duplicate these kinds of successes in other S&T areas with our innovative research and disruptive thinking, always trying to make our existing systems more effective and more affordable while improving transition to acquisition programs.

Our research is exhilarating and unpredictable. We balance a range of complementary but competing research initiatives by sup-

porting advances in established operational areas, while sustaining far-reaching long-term efforts to provide disruptive operational concepts.

Thank you again for your support, and I look forward to answering any of your questions.

[The prepared statement of Admiral Klunder can be found in the Appendix on page 80.]

Mr. THORNBERRY. Thank you.

Dr. Walker.

STATEMENT OF DR. DAVID E. WALKER, DEPUTY ASSISTANT SECRETARY OF THE AIR FORCE FOR SCIENCE, TECHNOLOGY AND ENGINEERING, U.S. AIR FORCE

Dr. WALKER. Chairman Thornberry, Ranking Member Langevin, members of the subcommittee and staff, I am pleased to have the opportunity to provide the testimony on the fiscal year 2015 Air Force Science and Technology Program.

Globalization and the proliferation of technology mean we face threats across a wide spectrum and competition across all domains. As stated by our chief of staff, in the Global Vigilance, Global Reach, Global Power Vision, quote: "Despite the best analysis and projections by the national security experts, the time and the place of the next crisis are never certain and are rarely what we expect," unquote.

Success and a guarantee of security in this dynamic environment require that we take lessons learned from the last decade of conflict, and creatively visualize future strategic landscape. In this space between the learning from the past and keeping an eye open on the future is where we find opportunity in the S&T environment. Air Force scientists and engineers continue to evolve and advance game-changing and enabling technologies which will transform the landscape of how we fly, fight, and win against high-end threats in the contested environments.

In close coordination with the requirements, intelligence, and acquisition communities, we have structured the Air Force 2015 Science and Technology Program to address the highest priority needs of the Air Force across the near-, mid-, and far-term, execute a balanced and integrated program that is responsive to the Air Force core missions, and to advance technical competencies needed to address future research thrusts.

Our forthcoming update for the Air Force S&T strategy focuses on investing in S&T for the future, as well as leveraging our organic capacity, the capacity of our partners both domestic and international, integrating existing capabilities, and to mature technologies into innovative, affordable, and sustained solutions. This flexible strategy provides us the technological agility to adapt our S&T program to the dynamic, strategic, budgetary, and technology environments that will shape prioritized, actionable S&T plans of the future.

It also guides our development of a strong STEM [science, technology, engineering, and mathematics] workforce and investment in our laboratory infrastructure to support the future research. The Air Force as a whole had to make difficult trades between force structure, readiness, and modernization in the service's fiscal year

2015 President's budget submission to recover from the budget uncertainties that we have had over the past few years. The Air Force fiscal year 2015 budget request for S&T is approximately $2.1 billion.

This year's S&T budget request represents a 6.2 percent decrease from our fiscal year 2014 President's budget request. However, when you compare this to the overall RDT&E decrease the Air Force had to take in the balance, which was about 9 percent, the Air Force S&T actually fared very well in the Air Force planning and programming process. Our budget request rebalances basic research spending as part of the overall portfolio to increase emphasis on conducting technology demonstrations.

It also emphasizes our efforts in game-changing technologies of hypersonics, autonomy, directed energy, and fuel-efficient propulsion technologies, which can affordably provide us necessary range, speed, and lethality for operations in highly contested environments, as outlined in the 2014 Quadrennial Defense Review. More information about these efforts and our investments in enabling technologies is described in my written statement, provided for the record.

In closing, I firmly believe that maintaining and even expanding our technological advantage is vital to ensuring the assured access and freedom of action in the air, space, and cyberspace. The focused and balanced investment in the Air Force fiscal year 2015 S&T program are hedges against an unpredictable future, and provide pathways to a flexible, precise, and lethal force at a relatively low cost in relation to the return on the investment.

On behalf of the dedicated scientists and engineers of the Air Force Science and Technology enterprise, I want to thank you again for the opportunity to testify today. And thank you for your continued support of the Air Force S&T program.

[The prepared statement of Dr. Walker can be found in the Appendix on page 96.]

Mr. THORNBERRY. Thank you.

Dr. Prabhakar.

STATEMENT OF DR. ARATI PRABHAKAR, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY, DEPARTMENT OF DEFENSE

Dr. PRABHAKAR. Thank you, Mr. Chairman, Mr. Langevin. And thanks to all of you for the chance to be here along with my colleagues today.

DARPA is part of this DOD S&T community. We are also part of the larger national R&D [research and development] ecosystem. Within those communities, DARPA has a particular role. And that role is to make the pivotal early investments that change what is possible so that we can take big steps forward in our national security capabilities. And that mission has not changed over our five and a half decade history as an agency.

But, of course, the world that we are living in has changed, and changed in that period. So what is going on today, as you well know, today we face a very wide variety of national security threats. We are dealing with challenges from nation-states, but

also networked terrorism. All of those actors today have access to very powerful technologies around the world.

And then here at home, we are watching the growing cost of our operational military systems. And that, too, poses a threat to our future security. So there is quite a lot on our plates. I would like to just briefly mention work across three different areas in our portfolio to give you a sense for some of the things we are doing about these challenges.

First, today we see that the classic approach to these complex military systems leads us to a place where these systems are so costly and inflexible that they are really not going to serve our needs for the next generation. So in the DARPA portfolio today you will find work that we are doing to come up with new techniques that are scalable approaches, for example, to dynamically controlling the electromagnetic spectrum. And you will see work in new distributed cooperative effects that we think can be a powerful part of the next generation of air dominance. Just two examples across a broad set of things that we are doing in this big bin of rethinking complex military systems.

In a second area, we can see the information revolution unfolding across every aspect of military operations. And today at DARPA, we are creating a new set of cyber security capabilities that will allow us to trust the information that we use. We are also inventing the new tools that let us get a handle on this explosion that is happening with data so that instead of drowning in the data we can actually get deep insights out of all of that information out there.

And then in a third area, we look at what is bubbling in research. And we see biology today starting to intersect with engineering. And in that research, we are seeing the seeds of technological surprise. So part of our work at DARPA today is making the investments to create new capabilities in areas like synthetic biology and neurotechnology. So just a few examples of the things that we are doing today.

I also just want to take a minute to talk with you about what it takes for us to do that work and to deliver on our mission. Your support across the board here has been critical. First, with respect to our people, we continue to use the 1101 flexible hiring authority that this committee has helped with the legislation on that, starting a number of years ago. It has actually become critically important to our ability today to recruit the next set of people that have the potential to become great DARPA program managers.

Secondly, let me turn to the budget. The President's budget request for DARPA in fiscal 2015 is $2.9 billion. The backdrop for that number is that our budget declined about 20 percent on real terms between 2009 and 2013. That includes the 8 percent sequestration hit in fiscal 2013. That downward slide stopped in fiscal 2014 and we had a slight restoration. About half the sequestration cut was restored in the 2014 appropriations.

I greatly appreciate the support from this committee that was part of making that possible. It is making a real difference this fiscal year. The President's budget continues that very slight restoration process, bringing us almost back to where we were before the sequestration. So, again, I will ask for your support of that request.

Let me just end by saying that when I talk to our senior leaders in the Pentagon and here on Capitol Hill, I can see the weight of our national security challenges on them. I see that on you, and we all feel it ourselves.

We do live in a volatile world. We all see the growth and the proliferation of threats. We are dealing with constrained resources. But I also know that American innovation has turned the tide time and again. And I am confident that our efforts today can do that for the years to come, as well. So thank you again for your support. We can't do that work without it.

And I am very happy to answer questions, along with my colleagues.

[The prepared statement of Dr. Prabhakar can be found in the Appendix on page 128.]

Mr. THORNBERRY. Thank you. Innovation can turn the tide if we let it. On the other hand, sometimes we have a way of getting in the way of things.

Mr. Langevin.

Mr. LANGEVIN. Thank you, Mr. Chairman. I want to thank all of our witnesses for your testimony today, and the just extraordinary and very important work that you all are doing. I have had the opportunity to meet with most of you pretty regularly, and I always appreciate the updates and the progress that you are making.

So let me start with this. It is my understanding that the High Energy Laser-Joint Technology Office budget was supposed to be restored in fiscal year 2015, after a 2-year reduction directed to assist the Air Force hypersonics program. The fiscal year 2015 budget does not reflect the restoration to approximately $68 million. Can you explain the rationale for this decision?

Mr. SHAFFER. Yes, sir. I will start, and I will let Dr. Walker finish. A lot of it got caught up in the overall budget reductions in 2015 that we had to deal with. But I don't look at the funding for high energy lasers in a vacuum of one particular program at the Joint Technology Office, but rather in the totality. And we have had remarkable progress, led not by the Joint Technology Office's money, but by their leadership in bringing together and knitting together the science and technology high energy laser programs of the Department.

And I think it is significant that this office, working with each of our S&T execs and with DARPA, have knitted together an integrated science and technology program that has led to—as you heard from Admiral Klunder—the deployment of a 30 kilowatt laser on the USS *Ponce* this summer. It has led to the development of what will eventually be a 100 kilowatt—currently, I think it is 10 kilowatt, Mary?—high energy laser mobile demonstrator for the Army that had a very, very successful demonstration at White Sands last December. I think it acquired somewhere around 88 out of 92 targets, something along that lines.

The Air Force is working on developing packaging and sizing of high energy lasers to go on their future fighter force to defend against incoming missiles. All of that was enabled by the Joint Technology Office. Not the money that they had, but rather the leadership that they showed. And I am very familiar with the people in that office.

Whether it is $68 million or $50 million, they are going to continue to show the leadership. And our overall investment in science and technology and high energy lasers across the Department is relatively stable. We can get the numbers for you and provide those to you. But high energy laser research is funded out of a number of programs in the Army, in the Navy, in the Air Force, and in DARPA. DARPA is doing remarkable things to drive up the efficiency of the electric lasers.

Dave, do you want to add anything else to that?

Dr. WALKER. No, what Mr. Shaffer says is exactly right. The program was funded to the level that we felt was necessary to continue the technology and support the joint services in developing lasers. However, the Air Force had budgetary pressures on it that didn't allow us to bring it back up to the full level that we wanted to. So everything took about a 6 percent reduction as we went through this fiscal year 2015, with things returning as we move into 2016 and beyond.

Mr. LANGEVIN. Well, let me ask the question a different way. Then are we right-sized with our budget with respect to directed energy right now? Or are we experiencing shortfalls that are hindering progress going forward on directed energy development weapons?

Dr. WALKER. Given the funding available, I believe the program is right-size given the year that we are in right now.

Mr. LANGEVIN. Well, let me turn to, so, another area then. And I am going to obviously follow this very closely. But I note that there were many mentions made in today's testimony on the need about—for robust STEM pipeline and the need to ensure that today's youth bring their talents to the national security arena. I find this hard to square with the proposed reduction in the National Defense Education Program [NDEP] to roughly half of its fiscal year 2014 level.

Can you elaborate on this decision, and can you provide an update on other relevant programs within the Department's purview, particularly those that reach K through 12 students?

Mr. SHAFFER. Yes, sir. Regrettably, that program is mine. So let me first address your first question in the reduction in the National Defense Education Program. First, that program previously had been made up of three separate projects, the first funding K through 12 education across the Department. And that was, order of magnitude, $12 million to $15 million. It floated up and down.

The second part of that program was a project called the National Science and Engineering Security Fellows Program. I made the decision to move that project from the office that it had been operated out of to our basic sciences office. The funding is still there, the project is still there, it is still doing the very same things. I just moved it from one program to another.

The third part of NDEP is the Science, Mathematics and Research for Transformation, or SMART, program. That is our program for service for scholarship. Effectively, we pay for undergraduate and graduate degrees, and then hire those people into our laboratories on a one year for one year scholarship-paid basis. In fiscal year 2015, we expect to have the same number of SMART scholars as we have in previous years.

So we have had no reduction in that part of the program. I moved another part of the program to another program element. And now you asked about the K through 12. The administration made the decision to streamline Federal education in certain areas. And part of that decision and part of that action was to move K through 12 funded efforts, with very few minor exceptions, to Department of Education.

So the funding that had been allocated for the K through 12 part in the National Defense Education Program was reallocated in the fiscal year 2014—or 2015 budget to Department of Education. And that is the simple part of the story. We are still trying to go out and use our scientists and engineers to stay contacted to K through 12. We are supporting the America First science event at the Washington Convention Center in April. So we are still outreached on K through 12, but the bulk of the funding was moved to Department of Education, sir.

And now I will turn it over to my colleagues to talk about their parts.

Ms. MILLER. So the Army was one of the exceptions. We did not lose our K through 12 Army Educational Outreach Program when they collected up the STEM programs and moved them out of the Department of Defense. And we find that it has been a very great value to the Army. It is doing outreach, and preparing children to understand the needs and importance of STEM. We interact with our laboratories, give them mentors and help bring them through that pipeline.

We bring them into the laboratories, where we can, to give them opportunities to understand technology as it applies to the Army. But we know that even if they don't choose to ever work for the Army, they certainly are informed and help the Army when they go to industry itself. One of the things that we have done in our program—and, we believe, helped to forestall it being taken away from the Department of Defense, too—is, we put in a process to have the quality of our program be assessed independently.

And we do have a contract in place with Virginia Tech that does look at our program and establishes how well we are effectively reaching these younger students. So we are certainly a proponent of this. We believe it is important for the workforce of the future.

Mr. LANGEVIN. Well, why was it okay for the Army to keep its program, but other areas of DOD you have moved it out and—to the Department of Education? My concern is that—and I am way over my time, and I will yield back after this. But my concern is that DOD loses its focus on preparing the next generation. And also leveraging the scientists and the capabilities that we have to really encourage our young people to go in this field and see that they are properly getting exposed to, and educated in the sciences.

I do think that DOD has a role to play. I guess, you know, this is certainly a policy decision. But I am concerned by the move the Department has made.

And I will stop there now.

Mr. SHAFFER. Sir, I would just like to say that it was an administration decision. It came down to us, we saluted, we executed. But I believe the Nation is well served by a Department of Defense that is in contact with our K through 12 students.

Mr. LANGEVIN. Thank you, Dr. Shaffer.

Mr. THORNBERRY. Mr. Nugent.

Mr. NUGENT. Thank you, Mr. Chairman. And I really want to echo some of the statements that Mr. Langevin made, particular in regards to—and I wasn't to go in this area, but on the STEM issue, I really do believe that we are better served. Not that Department of Education, I think it gets diluted. I think it is much more focused and much more directed in regards to what we are looking for for the future, whether it is DARPA or any of the services as it relates to innovation.

And I worry about innovation. I have three sons that serve this country. So our sons and daughters need you, need all the things that you can design, develop to make it—the battlefield safer for them, give them the opportunity to come home. And, Admiral, I am really interested in—and I am interested in all of you as it relates to directed energy. Mr. Langevin and I, I think, are pretty big proponents of directed energy because of what you mentioned in regards to—on the *Ponce,* in regards to actually testing, and the ability to test and what it costs to test versus shooting a missile off at a million dollars a copy versus a dollar.

Can you—we see programs in development stage. But then they tend to never make it to production, never make it to, you know, deployment. Where do we stand as it relates to that system on the *Ponce* in regards to the future?

Admiral KLUNDER. Yes, sir. Thank you for the question. And I will offer that there is—it is really a conviction by our senior leadership in the Department of the Navy. And what I mean by that is that we want those new innovative systems to be in the hands of sailors and Marines. We want them to tell us did we develop it right, did we develop and it needs to be tweaked a little bit? Or did we develop and we just didn't do it right? And we will bring it back.

But the point there is, you need to get a sailor or a Marine's hands on that thing, and tell them is it going to be effective in warfighting environment, and will it be affordable. So the point I would like to make, and thank you for your comments about innovation, we truly think that is the way this Nation was built and is the way we get in front of our adversaries. We don't want to run with them. I don't want a sailor or a Marine to ever go into a fair fight. I want them to always have the technological advantage so we always win and defend our Nation.

What we have done this time on the *Ponce,* I think is very credible, is I don't have a bunch of—my scientists and my colleagues, we developed it. But I have got real sailors right down there at Dahlgren, right now, on the system. And it is not a singular laptop over in the corner somewhere. It is a fully integrated console with our fully integrated combat information system on that ship.

So those young men and women on that—detachment of sailors are going to go out there. They are going to test it. And, indeed, we feel very comfortable because we have never missed so far. And that is one of the reasons why CNO Greenert said, "Matt, get it out there." We have never missed. We feel confident, though, that we would like to test it in that tough environment and see where it goes.

And the follow-on to the last bit of your question, I think regardless of the High Energy Laser-Joint Technology Office, I can assure you that we have got all the resources positioned in the Navy and Marine Corps to put us in a good place when this test is done. And I am not sure if you are familiar, but we also have a solid state laser technology maturation program that takes it to a much higher power level, and that is in 2016.

So when we finish this test on *Ponce,* this demo with real sailors, and we finish up the prototyping in 2016, we think we will be very well positioned for follow-on, long-term, enduring efforts.

Mr. NUGENT. And I just don't want us to—we can be in a testing mode forever.

Admiral KLUNDER. Yes, sir.

Mr. NUGENT. I mean, I think you might agree with that. And I would like to see us have at least a timeline as to when we want to have it operational. It goes back to CHAMP [Counter-Electronics High Power Microwave Advanced Missile Project]. Mr. Langevin and I have talked about that. It goes back to programs as it relates to the Army, and I know there is some collaboration between the Army and the Navy on those issues. And from my standpoint, I think that is great when you can get bright minds across the lines, across those services, to utilize that same information and make us all safer.

So my question back to you then is, if, after this test on the *Ponce,* if it meets the expectations, what would stand in your way of, if it is successful, in deploying that on other ships?

Admiral KLUNDER. I would say, nothing. Right now, we have already started the AOA [analysis of alternatives] on that process, that we are very familiar with the acquisition programs. We have already done all the blueprinting for the different classes of ships. So in many cases, if we are successful we see this as a possible weapons system for a number of classes of our ships. And I think it is important, too, if I could just give my colleagues to my right here a great shout out. Because we are doing a test down in your great State here in just a few months here to do some joint Army-Navy testing down at Eglin. And so I think that, again, shows the collaborative effort we do on directed energy.

Mr. NUGENT. And I think that is commendable, and it saves the taxpayers money, and it makes all of us safer in the long run.

So, Mr. Chairman, I yield back. And thank you so very much for all of your help.

Mr. THORNBERRY. Mrs. Davis.

Mrs. DAVIS. Thank you, Mr. Chairman. And thank you all for being here.

I wonder—and certainly, Director Prabhakar, if you could perhaps address this. What other governmental institutions of science, technology really support your efforts? And you talked about the intersection of biology and science. I am thinking of the NIH [National Institutes of Health], but I am wondering, as well, of what else does that, or to what extent does the NIH?

Dr. PRABHAKAR. I am very happy to try to answer that question because there is an answer for every aspect of our work. And let me start a little bit closer to home with much of what we do that goes directly into military systems. The folks at this table are the

people that we work directly with. Our people are working together on a daily basis. Because for a lot of those advanced technologies we need to understand operational needs, we need to understand what is going on with R&D and S&T activities across the services.

And then we—these are the people we end up working with to execute our programs and then to transition them. So that is one set of extremely important relationships.

But you are absolutely right that all of us rely on this larger national ecosystem. In the biology area, which, to me, that is much more of a research field, where we are just starting to find these new opportunities to build the kinds of technology capabilities that we need for national security. So we are—you know, it is a very different stage of maturity.

But absolutely, there, over and over again—whether it is work that we are doing on brain function research or on infectious disease—we find that we are building on top of the basic research that is almost always funded by the National Institutes of Health, sometimes by the National Science Foundation. You know, there are many billions of research dollars that have laid that foundation. We want to come along and find the places where we can build national security capabilities on top of it.

Mrs. DAVIS. Are there real differences about the way the labs produce in terms of the quality, the quantity of the research, as well? How do the defense labs compare to other industrial—other labs that we have?

Dr. PRABHAKAR. Yes. You know, to me, the starting point is to recognize that it is an ecosystem. And all these different entities—the performers of the research, and then the funders of the research—each have their own role. So, you know, just a simple example. I was visiting AFRL [Air Force Research Laboratory] last September and, you know, our folks have been working together on a couple of hypersonics programs. But I got to see, first-hand, some of the unique capabilities in that laboratory.

And that is exactly what you would expect, right? Where else would you expect to see fantastic hypersonics, leading edge understanding of this incredibly important, but very specialized technology? It should be at AFRL, and that is where you find it. But, you know, our work sometimes puts us in places where we want to be working directly with people in universities that are thinking about new ways to think about big data or some of these biology areas.

Frequently, we need to tap into the small entrepreneurial community. For example, in cyber it is pretty hard to think you are going to make—turn the corner on cyber issues without tapping into what is happening in this vibrant ecosystem of entrepreneurship. Some of—you know, a lot of those people don't even think they are in the national security business, but they are important to us.

Mrs. DAVIS. Absolutely. I am going to——

Dr. PRABHAKAR. We try to tap all of those.

Mrs. DAVIS [continuing]. Just shut you up a little bit because I don't have very much time.

Dr. PRABHAKAR. All right.

Mrs. DAVIS. Thank you. I appreciate your response. But I think, you know, it is true. I mean, there is all this interaction. And I guess sometimes we tend to be less than supportive of some of those other efforts. And when it comes to the NIH, I think, again, as we are facing decisions, budget decisions, we know that there is a tremendous—I think there is a tremendous interaction. And you have spoken to that.

Even in San Diego, they just formed the Cyber Center of Excellence. And I think that—I would hope that we could look to those innovative—the energies, really, in communities that are doing great work. I want to mention just very briefly—because I think we talked a little bit about innovation. And the importance of that, obviously, is very critical. And the shift to the Department of Education.

I guess our job here, too—there is the America Competes Act. Something that should be reauthorized. It is sitting in the Science Committee and not going anywhere. So I think—I mean, Mr. Chairman, I would—I think this is a committee that really could have an opportunity to have a sense of what role can we play, how can we have some input into that so that perhaps we can take a look and get something in that area moving that really does exactly what we are trying to do here.

And I hear, I think, from the response that nobody was probably, you know, jumping for joy that some of that came out of the military. And yet, on the other hand, I think we have to make it, I guess, understandable and usable, as well, throughout the school districts of our country. And how we can create that intersection, I think, is going to be important. And the America Competes Act is certainly one way to do that, where we improve and really do the best practices in terms of STEM education.

So thank you so much. Thank you, Mr. Chair.

Mr. THORNBERRY. Thank you.

Mr. Shaffer, let me ask you. David Berteau with CSIS [Center for Strategic and International Studies] has made a point, and I want to see if you agree with it. His point is that in previous—all previous military buildups the R&D funding has gone up at least at the rate of the buildup, if not faster. So that when there is the inevitable decline after that, you have got this reservoir of R&D projects to draw upon. But he says since 9/11 we really didn't do that.

The buildup went for intelligence and in operational things. We didn't have the big S&T, R&D buildup. And so this drawdown is even tougher because we don't have a reservoir from which to draw. Do you think that is true?

Mr. SHAFFER. To a partial extent, yes. I would have to go back and check the numbers. I think historically, when we have been a nation at war, actually the operations and maintenance accounts have risen faster than R&D. But S&T has come up a little bit. This last war we came up a little bit, and then went flat. I think there is a more important point, and we are trying to make this across the Department. And I think actually the best person who speaks about it is my boss, Under Secretary Kendall. And that is, R&D is not a variable cost.

So you—it takes the same amount of money to develop a new capability or a new weapons system irregardless of the force size. So we have to start thinking, as a Department, that stability in the long-term and funding for S&T is more important than the wild fluctuations.

And the 4 percent decline we had in fiscal year 2015, I can't tell you I like it. But I understand why we got there. Our job now is to protect against the out-years, and how do we make sure that there is enough money to maintain a viable S&T program that delivers new capabilities for the future force.

Mr. THORNBERRY. Well, I think that is true. I just think it is interesting that, you know, I guess we are all glad that these accounts are not cut more than they are. But we shouldn't overestimate, at the same time, what comes of that.

Let me back up kind of to what Mrs. Davis was talking about, and ask you all to respond briefly to this. As we have been talking about acquisition reform, obviously the swift pace of technology change is an enormous challenge. And actually, Dr. Prabhakar, you mentioned it earlier, too, how quickly things change.

I guess one of the things I would like to know, just—and within our limited time, just briefly, how do you—and I will start with you and go backwards. How do you and your organization keep track of the technology change in research universities and in the private sector? Y'all were talking about cyber for example. To make sure that it is—that you are aware of those broader technology changes, and then can pick and choose where DOD interests may benefit?

Dr. PRABHAKAR. I don't have a magic answer for you on that, except to say that I view that as integral to the job of each of our technical program managers. And, you know, when they come on board, as you know, they only are with us for typically about 3–5 years. My deputy, Steve Walker, and I have a custom of doing a brown bag lunch with the newest batch of program managers. And sit down and we talk with them, and one of the things we almost always talk about is how important it is to get out of your office in Arlington, Virginia, and go find what is happening in the technical arena.

Because there are people that know about us and they will bring us their ideas, but that is not enough for us. We have to be getting out and seeing what else is happening. And it is usually either in universities, sometimes it is in the startup community. Sometimes there will be a "skunkworks" tucked in the corner of a big established company. But you have to get out and visit people and see what they are thinking about in their labs and in their offices.

And I don't really know how to do it other than retail, but I find it essential to what we do.

Mr. THORNBERRY. Thank you.

Dr. Walker.

Dr. WALKER. The AFOSR [Air Force Office of Scientific Research] really has a mission in the Air Force of trying to reach out and find the best new ideas not only in the U.S., but internationally, as well. So having our offices spread across South America, Europe, and Asia allows us to reach out and find what are those good ideas and bring them into the U.S. to—for applications in the Air Force. In addition, within the U.S., the OSR program managers use their

6.1 dollars to go out and try to find innovative technologies and new basic research that they are able to apply, then, to Air Force problems.

So to use that as a seedling to move technology along. And as Dr. Prabhakar says, it has got to be an engagement. It is not a sit at home and hope people come to you. It is you have got to be out there visiting the people, seeing what the new ideas are, and bringing those forward. In addition, as we move into the more traditional directorates, they all maintain a basic research and early applied research capability, where they are reaching out to academia and industry trying to identify where are the best new ideas.

In addition to that, looking at the small business and where—through Small Business Innovative Research [SBIR] and other small business interactions that we have in the laboratory, really looking for those fresh new ideas. Putting out the calls. You know, a good example of this in our—both in our SBIR calls and in our RIF [Rapid Innovation Fund] calls. We have had 700, 800 people responding to these calls with new ideas that we are able to then pick the best of them and try to bring them forward for technologies for the Air Force.

So we have had great success, and we are trying to continue to keep that aperture open as possible to find the new innovative research that is going on out there.

Mr. THORNBERRY. Okay.

Admiral, do you all ever, as an addendum, do you all ever go out to venture capital community and see that they are investing?

Admiral KLUNDER. Absolutely. As a matter of fact, I like to call myself the venture capitalist of the Navy and Marine Corps. But to that point, Mr. Chairman, I won't repeat what Dave said, my colleague Arati, about the global look to—our eyes and ears are always open around America. That is academia, that is industry, that is laboratories. We are always looking. As a matter of fact, I will offer to you, the small grants, lots of seed corn, lots of petri dishes.

The kind of things a young man or woman in academia can do for literally soda pop and pizza is unbelievable. Specifically in the cyber domain that I know you are concerned about. Very small grants can be very, very beneficial for the team.

And I also offer—so America, we look globally, and we collaborate across all streams on these different offices. But something we have a distinct advantage, too, and it is specifically on cyber. Because I know, sir, you know. You wait a year or two, you have missed it.

They are already—they have already flipped that technology on you, and you are beat. So our point is that in the world that we can live in for Mr. Kendall—even in the 5,000 series acquisition document, we know it is pretty thick—we have the advantage that we can do user operational evaluation systems. What does that really mean? It means prototypes, specifically in cyber, on a defensive or offensive side if it is in an operational context.

But specifically defense and can we, indeed, bring that tool quickly, develop it quickly, get it out in prototype and see if it is going to be worthwhile. And then, if we have to, we go back and buy a number of them through Mr. Kendall in that acquisition

process. The point I am trying to make is, we can't wait that traditional timeline to do cyber work. We need to be able to get that technology developed, out there, in a year or two.

And that is something, I think, we have been able to do in my world, specifically, when I am able to control my 6.1, .2, and .3 dollars, sir.

Mr. THORNBERRY. How often do you do that?

Admiral KLUNDER. I do that a lot. And I do it for the Navy and Marine Corps. And we also work across agencies and other ones involved, sir.

Mr. THORNBERRY. Thank you.

Ms. MILLER. Sir, like my colleagues we have the Army Research Office that does our outreach to academia. They are always looking for those bright ideas that they can fund through our grants to our Single Investigator Program. We also have the Army Research Lab, which has a considerable amount of basic research. They are people that work within the Army, understand how to leverage that technology that we find in academia, and make it work on behalf of the Army.

As my colleagues, we also have our international technology centers. Most of the time we are colocated. And we do that global outreach to watch what is out there. The Army has established a capability that—they call it global tips online, where we see things that are international, good ideas from a technology perspective, and we put it on our Web site so that our Army researchers and our program managers can have access to that and figure out how to leverage it in the program.

And I can't underestimate the value of our subject matter experts being able to go to scientific conferences to exchange and—good ideas, and talk about where we are going in research. And incite people to want to do that research on behalf of the military needs. And finally, I would say—and Mr. Shaffer may choose to talk about this—we also have the Defense [Innovation] Marketplace, which is a Web site that we allow industry to identify IRAD opportunities, individual—or independent research and development activities that they have ongoing that we can then leverage.

And, in fact, from a service perspective we put out, for industry, what we are looking for, what capabilities we want for the future. All of this helps us to be able to leverage and find that research out there that we believe will be essentially important to the Army.

Mr. SHAFFER. Sir, my colleagues have all, I think, covered most of the points. We do have the Defense Marketplace. Seventeen percent of our budget actually goes out to universities, and we are in contact with universities. But I am not going to sit here and tell you that the picture is all rosy. As we went through the last year's budget, and we had travel restrictions placed upon our people and we did not allow our people, because of funding limitations, to go to technical conferences, we lost some contact.

And we are just starting to understand the impact of that. We have to watch that. I have to watch that very closely, and work every day to tell the story of why our people have to go out and be engaged because that is a good business decision. But I will tell you, as we go through a budget drawdown things like travel are always watched very closely, and my colleagues have to go ahead

and justify virtually every trip our young people want to make. That limits us.

Mr. THORNBERRY. Okay, thank you.

Mr. Langevin, you had a question?

Mr. LANGEVIN. Thank you, Mr. Chairman. So to our witnesses, I just want to just circle back to something I was going to raise in my opening statement, which I will now submit for the record. But there has been a steady crescendo of speculation about the coming wave of industry mergers and acquisitions. Are you confident in the Department's ability to maintain a competitive R&D environment, even through a potential contraction? And how would R&D concerns be addressed with any—within any larger oversight process?

Mr. SHAFFER. I guess I will start. But I will look for help from anybody at the table. I am actually fairly comfortable that even if we have some contractions and mergers that there will be industry to take up the effort. Now, I think that we may see a change. We may have to go more of a mix of big company and small companies. But, you know, one thing that is wonderful about America—and we are all sitting here bemoaning the fact that budgets are tight—at the end of the day we are spending $11.5 billion in science and technology, and $63 billion in research and development to develop new systems.

That is a lot of money, and that will create a lot of inducement for companies to stay in the game. And if there are mergers, for someone else to come in from outside. You know, the Federal statutes are very, very clear that we have to compete whenever possible. We encourage competition: $63 billion will buy a lot of competition. So I am not terribly worried yet. I haven't seen us get to the point, with very, very limited exceptions, of places where there isn't sufficient competition.

We monitor it. One of my colleagues, Elana Broitman, who is the Deputy Assistant Secretary for Manufacturing and Industrial Base Policy, monitors that on a daily basis. Concerned, but I don't see anything breaking yet. Would anybody like to add something?

Ms. MILLER. So I will just jump in there real briefly because I saw everybody put their hand up. But what I was going to say is, one of the things that we are looking at, trying to implement, is more of an open architecture design on most of our new systems coming up. That open architecture itself allows for more competition. So instead of having a one industry taking—or one industrial contract taking place, with one person being the primary performer, we now have competition at the subsystem levels and we maintain that competition. And that is something that we believe will help us in the future.

Mr. LANGEVIN. I am going to stop there and go to my next question, if I could. Thank you for those answers. But in a recent Defense Science Board [DSB] report from October of last year, titled "Technology and Innovation Enablers for Superiority in 2030," the board concluded that the opportunity for technological surprise is greatest for WMDs [weapons of mass destruction], and expressed concern about the ability to detect signatures associated with weapons of mass destruction, given the advancement of technologies that would reduce or even eliminate some of the signatures that we depend on today.

The impacts of such a technological shift would be extremely grave in many regards. And the board proposed a particular course of action, focusing on so-called "big data techniques," expressing the need for the Department to both work with, and head, commercial capabilities, but acknowledges the legal and privacy concerns associated with such an approach. Can you respond to that suggestion, as well as the underlying concern?

Dr. PRABHAKAR. Thank you. I think that DSB report put its finger on something that is, in fact, an important concern: the access that terrorist organizations, for example, have to all kinds of globally available technology; certainly including weapons of mass destruction, or the tools to create weapons of mass destruction. We recently started a program at DARPA that is specifically aiming to see what we can do with new technologies to try to counter those kinds of threats. I think they are very, very challenging threats.

And I agree with the DSB's report that—their comment about big data. I think that is a piece of the solution. The program that we have just launched is called SIGMA, and it is attempting to change the detector technology, but also figure out the networking and the big data approaches that it is going to take to really put a complete solution together to try to get us to a somewhat more safe environment.

Mr. LANGEVIN. Mr. Chairman, that is something we could follow up on a briefing that—if we could.

Thank you for that answer. Does anybody else have anything on that? Okay, then I will—let me move to Dr. Walker and Dr. Shaffer. Last year, the Department of Defense completed a successful joint concept technology demonstration for the Counter-Electronics High Power Microwave Advanced Missile Project, or CHAMP. What plans are underway to continue this effort? What are the limitations of the current technology? And what issues might prevent wider fielding of these sorts of high powered microwave weapons?

Dr. WALKER. So the demonstration was really the first opportunity to go out and use a high powered microwave from a cruise missile-size vehicle and to show that it actually worked. However, it is still a large form factor for an aircraft. Really like to get down to a smaller missile size. So the S&T side of the world is continuing to fund work on reducing the size of the device, as well as to increase the power to the device to give you better penetration, longer distance to standoff, as well as multiple shots out of a single cruise missile.

Really trying to get it down to a tactical missile form factor. In the meantime, in this year's budget request, the Air Force is requesting $5 million to initiate the analysis of alternatives on a non-kinetic weapon which would be—look at the CHAMP technology. The high powered microwave technology is one of the alternatives for how we go forward with a non-kinetic weapon in the future.

The Air Force has got, you know, severe constrictions on its modernization dollars, given all the things we have in our bucket right now. However, this is important enough that they were going to continue to moving forward, looking somewhere in the early 2020s as an opportunity to transition this type technology. The lab will continue developing the technology to ensure that when the Air

Force is ready to move forward with the program that we have the smaller size system ready to go forward and the technology up to a level that it is really ready to enter an acquisition program.

Mr. LANGEVIN. Some of this, though, is policy-related, as I understand it. Because some of the high powered microwave technology is deployable right now, as I understand it. And there has been some resistance, particularly in the Army as I understand it, to deploying some of that technology.

Dr. WALKER. I can just say from the Air Force side, since we developed the antipersonnel high powered microwave technology that has been developed, it is available to go. It has been a policy decision not to deploy it so far.

And I will hand that over to my colleagues.

Mr. SHAFFER. So I will start, and then let Ms. Miller talk. But I think it is very important to recognize that not all pulsed microwave or high powered microwave are the same types of systems. CHAMP was an incredible success. The program that the Army is looking at was a tremendous success, but they are totally different technologies. One is very, very short pulse, the other is continuous wave. There are policy implications about the deploying the ground-based high powered microwave and we are working through those.

The CHAMP, I think, or the pulse microwave, we will have a weapons system sometime in the 2020s that will be exquisite. And no one else in the world will have it. But we do have to work the size and the thermal management of that system.

But I think the really—and, you know, this—I shouldn't sound—I am going to sound like a geek. I think it is really cool that we finally got to the point where we demonstrated a capability and are on the pathway to deliver what we all grew up with as kids watching Buck Rogers employ.

Mr. LANGEVIN. Thank you. I just hope—and I will yield back, Mr. Chairman, in just a second. But I just want to say I hope that the policy decisions will be worked through aggressively so that it is not the policy that is holding back the deployment of the technology. Especially when it comes to keeping our troops safe, helping them be more effective. And, again, keeping the—ultimately, our country safer. Thank you.

Mr. Chairman, I yield back.

Mr. THORNBERRY. Well, I agree completely. And let me follow up. Who makes the policy decisions in this case? Is it the Department's policy shop, or someplace else? I mean, we have a technology, it is ready to be deployed. Policy decision says no, don't deployment—don't deploy it. Who makes that decision? Where do these issues get worked out?

Mr. SHAFFER. Sir, most of the time these things are led by our under secretary in policy, and we negotiate. We have a number of types of technology areas where we have to think about the policy implications. Autonomous platforms.

Mr. THORNBERRY. Yes. I am just focused on this one, as an example.

Mr. SHAFFER. You know, can I take it for the record and get back to you?

Mr. THORNBERRY. Yes.

Mr. SHAFFER. Because I don't have the exact——

Mr. THORNBERRY. If you don't mind.

Mr. SHAFFER. Absolutely.

[The information referred to can be found in the Appendix on page 151.]

Mr. THORNBERRY. Because I would—it is an issue in and of itself. If we have a technology that there is a decision not to deploy it, it is—kind of hard to get our arms around exactly who—how that decision was made. But then, it is also an example of some others that we may want to pursue.

Let me see if I can get in two more things right quick before we go vote, and y'all get to leave. All of this is about how much direct money investment we put into S&T. Obviously, we want the private sector to invest some of their own money in S&T along the way. Recently, the point was made to me that as long as we rely on lowest-cost technically acceptable contracts there is zero incentive for the private sector to put any of their own research into it.

They don't want to have any discriminators. All you want to do is be good enough, and then just cut, cut, cut, cut on the cost so that you win the contract. And so what that does, in effect, is discourage innovation and discourage the private sector from using their money to make improvements. Do you think that is true?

Mr. SHAFFER. Sir, not only do I think it is true, it is one of the key principles and tenets under Mr. Kendall's Better Buying Power 2.0. And that is, to better define the use of LPTA, low price technically accepted—or technically acceptable contracts. He believes it is okay to let those types of contracts for activities like mowing the base grass. It is not okay when you are going out and trying to compete a technically acceptable—or a technology contract.

He is aware of that. We are driving that out to the services. It will take time for people to recognize that. But I believe we have already made the change to move away from LPTA for technology—high-technology programs.

Mr. THORNBERRY. Anybody else have a brief comment on——

Admiral KLUNDER. I will just quickly say, Mr. Chairman, that if we are going to stay innovative, if we are truly going to leap ahead of our threats and our adversaries, you have got to get the performance. So I don't—we look for, obviously, game-changing affordability pieces when we bring that technology in. But I absolutely will not corrupt a contract to go low cost if I can't achieve the performance you and I need to defend this country.

So at the end of the day, that is what we got to have, and we do. So I promise you that, our contracts, we look for the performance of the system first. Then we will look at how the affordability can come out and play in terms of our—I am not talking about contracts. I am talking about the cost-effect of the system, sir.

Mr. THORNBERRY. I hear you. Okay.

Dr. WALKER. Yes. In the Air Force, one of the things we really focus on is that T-A-P, so that "technically acceptable" is a critical portion of that contracting mechanism. We have been working hard on trying to reenergize our engineering enterprise so we bring that technical confidence back so we can make that judgment. So that we really make the right decision and get the technology that we want, not just the lowest cost. So it is—the two pieces have to go

together, but it is not necessarily the best contracting vehicle for technology.

Mr. THORNBERRY. Yes, that word "acceptable" means you just kind of get good enough. I mean, that is what I hear. Rather than, oh, maybe with a little bit more you can—but something we may want to pursue. All right.

Let me ask this. If you could invest in only one technology program, one area of technology, one issue area, and—within your service, or y'all have broader leeway, obviously, what would it be? You have to narrow it down, and right now you can only invest in one. Ma'am?

Ms. MILLER. I would invest in materials.

Mr. THORNBERRY. Really?

Ms. MILLER. I would. I would tell you that the need to have new lightweight materials, affordable materials that can help us both in getting our power and energy uses down, getting our armor weights down, bringing down the soldier load, I mean it is kind of full spectrum. It covers, and is the underpinning of a lot of what we do. So I would say, for me, that is a big investment area.

Mr. THORNBERRY. That is interesting. Thank you.

Admiral KLUNDER. Well, Mr. Chairman, since I have already invested heavily in directed energy and railgun and undersea domain, I will tell you that the electromagnetic spectrum is the new one that we are working very hard on, sir, to make sure we understand, with my colleagues at DARPA, on how—and my other colleagues, how we can absolutely optimize that.

Mr. THORNBERRY. Okay.

Dr. WALKER. Since the Army is investing in materials, and we have got the electromagnetic spectrum covered——

[Laughter.]

Dr. WALKER. I would keep the investment in hypersonics as a key game-changer technology that we really need to move forward.

Mr. THORNBERRY. Really? Some people think that is not going to go anywhere. But you—if you had—the Air Force had one area of—to invest in for S&T, that is what it would be.

Dr. WALKER. For given, right now, where we are, we are on the cusp of a breakthrough.

Mr. THORNBERRY. Okay.

Dr. WALKER. Following X–51, I think there is a real opportunity to change warfighting with hypersonic capabilities.

Mr. THORNBERRY. Interesting.

Dr. Prabhakar.

Dr. PRABHAKAR. Mr. Chairman, I am going to give you a DARPA answer.

Mr. THORNBERRY. Ahh.

Dr. PRABHAKAR. Which is that if we only invest in one we are just not going to get there. Because the problems that we are dealing with are actually too complex for any one silver bullet. And I think rethinking the entire systems approach is actually going to be central to this next generation of advanced military capabilities.

Mr. THORNBERRY. Which may be an area in and of itself in which to invest. I mean, I—you know, we talk about—for example, with terrorism we talk about a—fighting a network with a network. We have to understand networks better in order to do that, and that—

it—you know, it is not what we traditionally think of as investment in S&T. But maybe that is, you know, one——

Dr. PRABHAKAR. You are completely right. And you are going to need all of these other pieces so that you got the pieces——

Mr. THORNBERRY. Yes. No. I know you are right about that. But it is interesting.

So, Mr. Shaffer, you got one?

Mr. SHAFFER. I actually do. I agree with Arati, I agree with all my colleagues. But I am a simple guy. At the end of the day our business is in defense of the homeland. I am more concerned about what can happen to the homeland through a cyber attack launched against the U.S. I would defend—or invest in cyber above all else just because of the potential gravity of that attack.

Mr. THORNBERRY. Yes, yes. Fair point. All good answers.

Thank you all very much for being here, for what you and your folks do for the country.

With that, the hearing is adjourned.

[Whereupon, at 4:07 p.m., the subcommittee was adjourned.]

APPENDIX

MARCH 26, 2014

PREPARED STATEMENTS SUBMITTED FOR THE RECORD

MARCH 26, 2014

HOLD UNTIL RELEASED
BY THE COMMITTEE

STATEMENT TESTIMONY OF

MR. ALAN R. SHAFFER
PRINCIPAL DEPUTY, ASSISTANT SECRETARY OF DEFENSE FOR DEFENSE RESEARCH AND ENGINEERING

BEFORE THE UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON ARMED SERVICES

SUBCOMMITTEE ON INTELLIGENCE, EMERGING THREATS AND CAPABILITIES

MARCH 26, 2014

Chairman Thornberry, Ranking Member Langevin, members of the Committee, I am pleased to come before you today to testify about the state of the Department of Defense's science and technology (S&T) program. I am proud to be here representing the roughly 100,000 scientists and engineers in the science and engineering (S&E) workforce, a workforce that has had remarkable achievements in the past, but is now a workforce showing the early stages of stress due to downsizing and the budget challenges of the last year. This past year has been unlike previous years in our community; the collective impact of the sequester-forced civilian furlough and program curtailment, the October 2013 government shutdown, and the indirect impacts of the sequester, such as restrictions on our young scientists and engineers attending technical conferences, has impacted the health of our workforce and the programs they execute in ways that we are just beginning to understand. We have begun to address these challenges but they remain a concern for us.

INTRODUCTION

The FY 2015 budget request for science and technology (S&T)[1] is relatively stable, when compared to the overall DoD top line[2] and modernization accounts. The DoD S&T request is $11.51 billion, compared to an FY 2014 appropriation of $11.98 billion. This request represents a 4% decrease (5.6% in real buying power) in the Department's S&T compared to Research, Development, Test and Evaluation (RDT&E) account that was virtually unchanged. While we continue to execute a balanced program overall, there are factors that led Secretary Hagel to conclude in his February 24, 2014 FY 2015 budget rollout that "we are entering an era where American dominance on the seas, in the skies, and in space can no longer be taken for granted".[3]

Simultaneous with the challenges of balancing a reduced budget and continuing to engage the total defense workforce in meaningful research and engineering (R&E), the capability challenges to our R&E program are also increasing. This is attributable to changes in the global S&T landscape and the acceleration globally of development of advanced military capabilities that could impact the superiority of US systems. The convergence of declining budgets, in real terms, and increased risk is not a comfortable place to be. However, as I will highlight in the latter sections of my statement, the Department has begun to reshape the focus of our technical programs to address some of our new challenges. We are also beginning to shift our programs to better position the Department to meet our national security challenges. Finally, we have some areas where we need your help in order to be successful executing our FY 2015 budget. I will cover these areas at the end of my statement.

[1] Science and Technology is defined as program 6, budget activities 1, 2, and 3; frequently called 6.1, 6.2, and 6.3 (basic research, applied research, and advanced technology development); Research and Engineering adds Advanced Capability Development and Prototyping (6.4).
[2] Top line refers to the total funds appropriated by Congress to include "supplemental" or Oversees Contingency Operations funds
[3] Remarks by Secretary Hagel on the FY 2015 budget preview in the Pentagon Briefing Room on 24 February 2014.

FY 2015 PRESIDENT'S BUDGET REQUEST

The current fiscal environment presents significant challenges to the DoD budget. The Department is in the third year of a protracted overall topline and RDT&E budget drawdown. As highlighted by Secretary Hagel, there are three major areas that comprise the Department's budget: force size, readiness, and modernization. The current budget is driving a force reduction, but this reduction will take several years to yield significant savings. In the FY 2015 budget, readiness and/or modernization will pay a larger percentage of the "bill". As a former airman who entered service in the 1970's, I am very well aware of what happens when savings are gleaned from readiness – the hollow force is not acceptable. Over the next several years of the budget we expect modernization accounts (Procurement and RDT&E) to pay a large portion of the Department's fiscal reduction bill. At the same time, Secretary Hagel's strategy is to protect advanced technologies and capabilities. The FY 2015 budget must balance all of these drivers; we believe we have done well, but do acknowledge there is increased risk.

The last several budgets have been characterized by instability and rapid decline of the modernization accounts. The FY 2013 sequestration reduced all accounts by 8.7%; for S&T, this amounted to a loss of about $1 billion. The December 2013 Bipartisan Budget Act increased the discretionary caps in FY 2014 and FY 2015 to provide some relief, but less in FY 2015 than FY 2014. From FY 2013 to 2015, the S&T program operated with reductions of $1.5 billion compared to what had been planned in the FY 2013 budget.

One of the key points for S&T of the FY 2015 budget is a shift in focus at the macro scale from basic research to advanced technology development and a shift from the Services to DARPA to develop advanced capabilities. In FY 2015, we funded DARPA at the same level, after inflation, as was funded in FY 2014. These numbers are shown in Tables 1 and 2.

	PBR 2014 ($M)	PBR 2015 (FY 14 CY $M)	% Real Change from PBR 2014 (FY 14 CY $)
Basic Research (BA 1)	2,164	2,017 (1,982)	-8.41%
Applied Research (BA 2)	4,627	4,457 (4,378)	-5.38%
Advanced Technology Development (BA 3)	5,192	5,040 (4,951)	-4.64%
DoD S&T	**11,984**	**11,515 (11,311)**	-5.61%
Advanced Component Development and Prototypes (BA 4)	12,057	12,334 (12,116)	0.49%
DoD R&E (BAs 1 – 4)	**24,041**	**23,849 (23,427)**	-2.55%
DoD Topline	526,612	495,604 (486,841)	-7.55%

Table 1— Defense Budget for Science &Technology; Research & Engineering; and DoD Top Line Budget (President's Budget Request 2014 compared to 2015.

Science & Technology	PBR 2014 $M	PBR 2015 (FY 14 CY $M)	% Real Change from PBR 2014 (FY 14 CY $)
Army	2,205	2,205 (2,166)	-1.76%
Navy	2,033	1,992 (1,957)	-3.95%
Air Force	2,270	2,129 (2,091)	-7.88%
DARPA	2,793	2,843 (2,793)	0.0%
Missile Defense Agency (MDA)	350	176 (173)	-50.55%
Defense Threat Reduction Agency (DTR	495	473 (465)	-6.16%
Chem Bio Defense Program (CBDP)	449	407 (400)	-11.02%
Other Defense Agencies	1,389	1,290 (1,267)	-8.74%
DoD S&T	**11,984**	**11,515 (11,311)**	-5.61%

Table 2 - Service and Agencies S&T Budgets (President's Budget Request 2014 compared to 2015)

Research and Development is not a Variable Cost

Over the past decade, the R&D accounts have been quite variable, but this counters one of the key tenets of R&D investment made by the Honorable Frank Kendall in discussing the FY 2015 budget. There has been a tendency in the past to reduce research and development more or less proportionately to other budget reductions. This tendency, if acted upon, can be detrimental because research and development costs are not directly related to the size of our force or the size of the inventory we intend to support. The cost of developing a new weapons system is the same no matter how many units are produced. In a recent speech, Secretary Kendall explained the invariant nature of research and development this way:

> R&D is not a variable cost. R&D drives our rate of modernization. It has nothing to do with the size of the force structure. So, when you cut R&D, you are cutting your ability to modernize on a certain time scale, period -- no matter how big your force structure is.[4]

If we don't do the research and development for a new system than the number of systems of that type we will have is zero. It is not variable.

Secretary Kendall said it this way:

> [T]he investments we're making now in technology are going to give us the forces that we're going to have in the future. The forces we have now came out of investments that were made, to some extent, in the 80s and 90s…if you give up the time it takes for lead time to get…a capability, you are not going to get that back."[5]

[4] Honorable Frank Kendall presentation to McAleese/Credit Suisse FY 2015 Defense Programs Conference on 25 February 2014.
[5] Kendall, 25 February 2014.

There is another trend impacting the Department's ability to deliver advanced capabilities. Recent data from the Nation Science Foundation shows an upward trend in industry R&D spending compared to a downward trend in federal government R&D spending (Figure 1). Industry in the United States performs roughly 70% of the Nation's R&D with the federal government and academia making up the remaining 30%. Figure 1 also shows the dependence of academic researchers on federal government funding, as noted by the National Science Board:

Most of U.S. basic research is conducted at universities and colleges and funded by the federal government. However, the largest share of U.S. total R&D is development, which is largely performed by the business sector. The business sector also performs the majority of applied research. [6]

This implies that DoD needs to be more cognizant of industry R&D as part of our overall capability development and remain sensitive to the importance of federally funded academic research. We continue to push in these areas through our continued support of the university research portfolio and our recent emphasis on Independent Research and Development (IR&D).

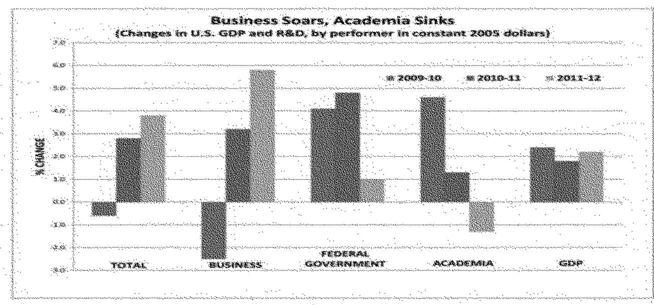

Figure 1 - Changes in US GDP and R&D by Performer[7]

SCIENCE AND ENGINEERING WORKFORCE

The Department's scientist and engineering (S&E) workforce consists of in-house labs, engineering centers, test ranges, acquisition program offices and so forth, and is augmented by our partners in the federally funded research and development centers (FFRDCs) and University Affiliated Research Centers (UARCs). The talented scientists and engineers working within these organizations form the foundation of the Department's technology base and are responsible for conceiving and executing programs from basic research through demilitarization of weapon systems. The technical health of this workforce is a priority for me and the Department.

[6] National Science Board. 2014. *Science and Engineering Indicators 2014*. Arlington VA: National Science Foundation (NSB 14-01).

[7] Science magazine. 13 January 2014. Retrieved from http://news.sciencemag.org.

Our in-house labs have been designated by Congress as Science & Technology Reinvention Laboratories (STRL) providing the directors of these facilities special authorities to manage their workforce via pay-for-performance personnel systems. Each director is granted flexibility to create workforce policies unique to his/her lab with new personnel initiatives being transferable to other STRLs if proven to be effective in the hiring, retention and training of S&Es. Each year my office works with the Services and their labs to ensure they have the authorities our lab directors need. Recent accomplishments include direct hiring authority for bachelors, masters and doctoral level graduates, increase in the number of technical senior executive billets, and authority for lab directors to manage their workforce based upon available budgets.

Data from the Strategic Human Capital Workforce Plan published in September 2013 indicates that our lab workforce is getting older. From 2011 to 2013, the average age of our scientists and engineers in our labs has grown from 45.6 years to 45.7 years for scientists and from 43.2 years to 43.9 years for our engineers. Although the change seems minimal over the past two years, it reverses the trend over the past decade when we had been driving the average age down. Data from the Science and Technology Functional Community indicate that the combination of fewer new hires and retirement-eligible employees working longer both contribute to the increase in average age. In 2013, there were only 731 new hires in the S&T Functional Community, whereas in 2010 there were 1,884. In 2010, retiring workers were retirement-eligible for an average of only 4.1 years. From 2011-2013, that average grew to 4.5 years. The trend indicates that we may not be replacing our seasoned employees with enough young scientists and engineers who will shape our future. This could be an indicator of older employees working longer because of a down economy or it could be an indicator that we are not hiring or retaining enough young scientists and engineers.

Although anecdotal, we are seeing a trend in why younger workers may be leaving. We saw a number of young scientists and engineers leave in 2013, early in their career. In conducting exit interviews, our laboratory directors reported that these young workers consistently cited travel and conference restrictions, as well as perceived instability of a long term career as motivating factors for their departure. This information, although anecdotal, is of concern; consequently, we are attempting to gather data to see if we can discern a definite signal.

Another area of significant Department and national interest is building a robust science and engineering workforce through various Science, Technology, Engineering, and Mathematics (STEM) initiatives. My office recently created the STEM Executive Board who has the authority and continues to provide strategic leadership for the Department's STEM initiatives.

Significant change to the Federal portfolio of STEM programs has occurred over the past year. In response to the requirements of the America Competes Reauthorization Act of 2010, Federal STEM-education programs were reorganized with the goals of greater coherence, efficiency, ease of evaluation, and focus on the highest priorities. This resulted in the Federal STEM Education 5-Year Strategic Plan designating the Smithsonian, Department of Education and National Science Foundation as lead agencies in implementing this plan. The DoD STEM Strategic plan is aligned with the federal plan to achieve Federal and Departmental STEM education goals.

We are also developing department-wide guidance on STEM program evaluation, coordinating within the Department and across the Federal government to improve effectiveness and efficiencies in these investments in future workforce needs. A DoD STEM Annual Report, expected to be delivered in FY 2015 based on FY 2014 data, will communicate the activities and results in achieving Departmental goals.

In summary, budget constraints, furloughs, and conference and travel restrictions have contributed to a drain on our most valuable resource – people. To replace our losses and rebuild our workforce for the future, we are working on bringing stability back to our S&E programs, give our people challenging while enriching environments in which to work.

CHALLENGES TO MAINTAINING TECHNOLOGICAL SUPERORITY

The United States has relied on a DoD that has had technological superiority for the better part of the post-World War II era. There are factors that are converging such that the DoD maintaining technological superiority is now being challenged. These challenges come from both changes in the way technology matures and in advanced capabilities being developed in the rest of the world. The Department is emerging from over a decade of focusing on countering terrorism and insurgency. While the challenges of counter terrorism remain, new national security challenges are emerging. Other nations are developing advanced capabilities in areas such as: cyber operations, advanced electronic warfare, proliferation of ballistic missiles for strategic and tactical intent, contested space, networked integrated air defenses, and a host of other capabilities stressing the Department's capability advantages. The Department's S&T program is being re-vectored to meet these new challenges. In addition, the Department is shifting to a focus on the Asia-Pacific region, a region with unique and challenging geographic and cultural features. Most notably, the geographic extent of the Asia Pacific region adds new challenges in terms of fuel efficiency and logistics.

In short, the Department and Nation are at a strategic crossroads—the funds available to the Department (and national security infrastructure in general) are decreasing, while the complexity and depth of the national security challenges are growing. The world we live in is an uncertain place. Secretary Hagel said it best in his recent roll out of the FY 2015 budget:

> "The development and proliferation of more advanced military technologies by other nations that means that we are entering an era where American dominance on the seas, in the skies, and in space can no longer be taken for granted." [8]

Secretary Hagel went on to say:

> "To fulfill this strategy DoD will continue to shift its operational focus and forces to the Asia-Pacific, sustain commitments to key allies and partners in the Middle East and

[8] Remarks by Secretary Hagel on the FY 2015 budget preview in the Pentagon Briefing Room on 24 February 2014.

Europe, maintain engagement in other regions, and continue to aggressively pursue global terrorist networks." [9]

Global Changes in S&T Impact Technology Development. The nature of the international technology landscape is much different than it was even 20 years ago in two fundamental ways:

1) Many technologies of importance to the Department's capability developments are driven by the commercial sector, and have become a global commodity.

2) The pace of maturation of technology is accelerating; that is, technology maturation occurs on a more rapid scale than in the past.

Our DoD S&T community needs to identify areas where technology has become a global commodity and not expend resources working to develop the same capability. We must track global technology developments, harness them and apply the technology to our needs. This year, we have initiated a project at the Defense Technical Information Center to improve our ability understand global technology development, and are in pilot phase to use automated tools to assess technology advances.

We already know that industry drives most microelectronics and semiconductors development; older infrared focal planes, routine communications, computers. The technology coming from these sectors is sufficient to meet most DoD capability needs. The DoD should be an adopter, not a leader in these areas while addressing the unique security concerns of these technologies used in our military, cyber and IT systems. The DoD should focus our research in technology integration or in developing technologies into products at performance levels beyond those commercially available or planned. Examples would include electronic travelling wave tubes (led by Naval Research Lab), which provide higher frequency and higher power output than is needed in commercial applications; and infra-red (IR) "super lattice" semiconductors (led by the Army's Night Vision Laboratory), which give high enough resolution in IR to make "movies" out of simple data and images. The DoD should monitor and apply these technologies to meet our needs.

At the same time, we know that the time to mature many technologies is decreasing. We have seen the time from invention to market penetration decrease by a factor of two over the past half century. Consequently, I would like to cite comments made by Mr. Frank Kendall, Under Secretary of Defense for Acquisition, Technology, and Logistics, who states that one of the key factors to maintaining technological superiority is to maintain a steady investment in technology.

"The effects of time (lost) cannot be reversed. It is well understood in the R&D community, and most particularly in the S&T community, that the investments we make today may not result in capability for a generation. It takes upwards of 5, 10, even 20 years to develop a new system, test it, and put it into production. By taking higher risks and accepting inefficiencies and higher costs we can reduce the "time to market" of new weapon systems; in fact, we have reduced this time … with reforms put in place in recent years."

[9] Hagel, 24 February 2014.

Even during World War II we fought with the systems that had been in development for years before the war began. We can shorten, but not eliminate the time required to field new cutting edge weapons systems. But one thing is for sure, if we do not make R&D investments today, we will not have the capability in the future.

Capability Changes to DoD Technology Superiority. More significant than the changes in how technology is developed and delivered globally are changes in military capabilities being developed by other nations.

I will cite just one example; there are many more. The convergence of advanced digital signals and computer processing has given rise to proliferation of a new class of system—the digital radio frequency memory (DRFM) jammer. DRFM jammers are fairly inexpensive electronic systems that ingest the radar (or communications) signal, analyze the digital waveform, and then generate random signals, with the same waveform, back to the transmitting radar receiver. The result is the radar system sees a large number of "electronic" targets. If the US employed conventional weapons systems using the traditional methods, we could shoot at or chase a lot of false targets. The consequence is that the US needs to develop a counter to DRFM jammers.

The convergence of computer processing, digital signal processing, digital electronics, optical fibers, and precise timekeeping are giving rise to inexpensive enablers that can improve the ability to counter conventional weapons platforms. We are starting to see other nations advance technologies to counter US overmatch by combining the components listed above to enhance capabilities in electronic warfare, longer range air-to-air missiles, radars operating in non-conventional bandwidths, counter-space capabilities, longer range and more accurate ballistic and cruise missiles, improved undersea warfare capabilities, as well as cyber and information operations. We see these types of new capabilities emerging from many countries; to include China, Iran, Russia and North Korea. This has led to a situation where, in the next five to ten years, US superiority in many warfare domains will be at risk. Accordingly, the following section highlights some of the areas where we are watching.

Proliferation of Weapons of Mass Destruction (WMD). The 2013 National Security Interests published by the Chairman of the Joint Chiefs of Staff lists as the top priority interest "Survival of the Homeland". The one existential threat to the United States comes from Weapons of Mass Destruction. Traditionally, WMD has included nuclear, chemical and biological weapons and their delivery systems. The emergence of new countries with nuclear ambitions, such as North Korea and Iran, make today's world much more dangerous. Chemical and biological weapons, used in both World Wars, have been resurgent in the past two decades. Perhaps the gravest danger for the United States and the rest of the world is the possibility of WMD falling into the hands of terrorist groups and other groups in the midst of instability. We must continue our vigilance in this area and continue to develop ways to deal with their use.

The United States is currently rebalancing to the Asia Pacific region. As we do so, the Department is faced with a host of new challenges. I will discuss some of the challenges over the next several paragraphs.

Vulnerability of the US Surface Fleet and Forward Bases in the Western Pacific. US Navy ships and Western Pacific bases are vulnerable to missile strikes from ballistic and cruise missiles already in the inventory. China has prioritized land-based ballistic and cruise missile programs to extend their strike warfare capabilities further from its borders. Chinese military analysts have concluded that logistics and power projection are potential vulnerabilities in modern warfare, given the requirements for precision in coordinating transportation, communications, and logistics networks. China is fielding an array of conventionally armed ballistic missiles, ground- and air-launched land-attack cruise missiles, special operations forces, and cyber-warfare capabilities to hold targets at risk throughout the region. The most mature theater missiles are the DF-21 C/D, which both have 1,500 km radius. They are also developing a longer range missile that would be able to strike as far as Guam. These ballistic missiles are coupled with advanced cruise missiles that could threaten any surface warfare fleet by 2020.

The People's Liberation Army (PLA) Navy has the largest force of major combatants, submarines, and amphibious warfare ships in Asia. China's naval forces include some 79 principal surface combatants[10], more than 55 submarines, 55 medium and large amphibious ships, and roughly 85 missile-equipped small combatants. The first Chinese-built carrier will likely be operational sometime in the second half of this decade. In the next decade, China will likely construct the Type 095 guided-missile attack submarine (SSGN), which may enable a submarine-based land-attack capability. In addition to likely incorporating better quieting technologies, the Type 095 will likely fulfill traditional anti-ship roles with the incorporation of torpedoes and anti-ship cruise missiles (ASCMs). Since 2008, the PLA Navy has also embarked on a robust surface combatant construction program of various classes of ships, including guided missile destroyers (DDG) and guided missile frigates in addition to more modern diesel powered attack submarines.

US Air Dominance. We see the same trend—development of systems to push US freedom of movement further from the Asia mainland. China is developing an integrated air defense system that could challenge US air dominance and in some regions, air superiority is challenged by 2020. The challenge to our air dominance comes primarily through the aggregation of capabilities starting with an extensive integrated air defense system (IADS), moving to development of advanced combat aircraft, to enabling technologies, primarily electronic warfare capabilities. China is demonstrating a systems approach through advanced aircraft design of 5th generation fighters, advanced combat systems, and advanced dense long range, networked air defense systems. It should be noted that others (such as Iran, Syria, and North Korea) are developing well integrated air defense systems. The PLA Air Force is continuing a modernization effort to improve its capability to conduct offensive and defensive off-shore operations such as strike, air and missile defense, strategic mobility, and early warning and reconnaissance missions. China continues its development of stealth aircraft technology, with the appearance of a second stealth fighter following on the heels of the maiden flight of the J-20 in January 2011, a 5th generation fighter scheduled to enter the operational inventory in 2018.

Vulnerability of US Satellites in Space. China has been rapidly expanding both the number, and quality of space capabilities; expanding its space-based intelligence, surveillance,

[10] As of 2013

reconnaissance, navigation, meteorological, and communications satellite constellations. In parallel, China is developing a multi-dimensional program to rapidly improve its capabilities to limit or prevent the use of space-based assets by others during times of crisis or conflict.

China continues to develop the Long March 5 (LM-5) rocket, intended to lift heavy payloads into space, doubling the size of the Low Earth Orbit (LEO) and Geosynchronous Orbit (GEO) payloads China can place into orbit. During 2012, China launched six Beidou navigation satellites completing a regional network and the in-orbit validation phase for the global network, expected to be completed by 2020. From 2012-2013 China launched 15 new remote sensing satellites, which can perform both civil and military applications. China will likely continue to increase its on-orbit constellation with the planned launch of 100 satellites through 2015. These launches include imaging, remote sensing, navigation, communication, and scientific satellites, as well as manned spacecraft.

Research and Engineering Strategy

To address the challenges of an accelerating, globalized research and development environment coupled with pressurized DoD budgets and the rapid growth of capabilities in other nations, we needed to examine the strategy we are using to focus the DoD investment on high priority areas.[11] To develop the research and engineering strategy, we had to go back to first principals. Why does the Department conduct research and engineering? What does the Department expect the DoD R&E program to deliver? After examination, we contend the Department conducts research and engineering for three reasons, in priority order:

1) ***Mitigate new and emerging threat capabilities***—the Department must defend the homeland and overseas forces and national interests against threats that exist today, and threats that are still in development.

2) ***Affordably enable new or extended capabilities in existing military systems***--Coincident with a tighter budget, and the fact that time is not recoverable, the DoD R&E program should focus on controlling costs, both in existing and future weapons systems.

3) ***Develop technology surprise***—Finally, throughout the past century, the nation and the Department have looked to the Department's R&E program to continually develop and mature new capabilities that surprise potential adversaries.

Priority 1: Mitigating or Eliminating New and Emerging Threats to National Security

The Department must be prepared to meet its current and future national security missions, which include defending the homeland, securing freedom of navigation, and being able to project power. The research and engineering priorities inherent in this principal also include protecting the nation against nuclear, chemical, and biological weapons, from both state and non-

[11] While the priorities listed below capture the cross-DoD priorities, there are still individual Service priorities they must address. These priorities do not address Naval responsibilities for the Ocean, Army responsibilities for the ground or Air Force for the Air. Rather, they comprise a set of areas that must be addressed across component. It is interesting to note the large efforts in the Services and DARPA largely align with the strategy.

state actors. This principal also includes protecting the nation against new threats, such as cyber operations and the proliferation of cruise missiles and UAVs. The final emerging vector in this area is to find solutions to the new capabilities that would prevent the US armed forces from fulfilling our global mission, such as electronic warfare and maintaining space capabilities.

Countering Weapons of Mass Destruction (C-WMD). The Department's investment in countering weapons of mass destruction is made primarily by the Defense Threat Reduction Agency and the Chemical Biological Defense Program, as well as the Army. All totaled, the Department's investment in C-WMD is about $800 million per year. Countering weapons of mass destruction poses some unique challenges because of the urgency and immediacy of the threats, the fact that threats present low probability but high consequence events, and that there is a need for on-call, comprehensive expertise. The Defense Threat Reduction Agency emphasis for FY 2015 include kinetic and non-kinetic means to counter and defeat WMD in non-permissive environments, low visibility search (and identification) for all threats (nuclear and chemical/biological), global situational awareness through mining large, diverse datasets, application of autonomy to reduce risk to the human, persistent intelligence, surveillance and reconnaissance (ISR) for WMD, WMD modelling and simulation, and operating in a high electromagnetic pulse environment. To date, we have not identified the "silver bullet" solution, so a sizable portion of the C-WMD program involves international and interagency partnership.

Emerging trends over the last year includes the need to counter threats as far "upstream" or left of event as possible. Therefore, the entire C-WMD community is strengthening their program to interdict / render safe WMD before they are used.

Missile Defense. In FY 2015, the investment in missile defense S&T dropped from roughly $350M in FY 2014 to $176M in FY 2015. Yet, missile defense remains a priority. The reduction in missile defense is more than offset the Navy and by the Office of the Secretary of Defense efforts in electromagnetic rail gun technology; a nearly $200M investment in FY 2015. This push in rail gun is being made to determine if the technology is mature enough to field an inexpensive, kinetic kill system to intercept theater ballistic missiles in terminal and mid-course. The current investment supports demonstration of an advanced rail gun against a missile surrogate in 2015.

Although not a capability that will be fielded soon, the Missile Defense Agency continues to look at Directed Energy for missile defense. They are the primary investor in both hybrid (diode pumped alkaline laser) and fiber lasers. Significant demonstrations for both of these directed energy capabilities will occur in 2015 to 2016.

A strategy based on only kinetic defense which requires a high-end US missile intercept against this proliferation of missiles is cost-imposing on the United States. Our research and engineering program is also working on developing non-kinetic capabilities and less expensive kinetic capability to reduce the effectiveness of potential adversaries' missiles; we are making strides in this area.

Cyber and information operations. The Department's investment in Cyber S&T in FY 2015 is $510M. With the growing reliance of modern military forces on information technology,

cyber operations will play an increasingly important role in ensuring continuity of missions in the physical domains. Having effective technologies to support those cyber operations makes cyber security research an essential element in our long-term abilities to defend the nation.

This year, the Department rebuilt the cyber S&T investment around warfighting capability requirements. We have then built a strong integrated technical foundation across the Cyber research and engineering enterprise through our Cyber Community of Interest, a group made up of Senior Executive Service representatives from the Services, NSA, and my organization. Our cyber S&T investments are guided by an S&T Capabilities Framework that captures new and emerging mission requirements including improved situation awareness and course of action analysis. The framework has been developed with participation of all the Services as well as the Intelligence Community, National Laboratories, and our Federally Funded Research and Development Centers. We are placing emphasis on broadening the research beyond standard computing systems to include defending against cyber threats to tactical and embedded systems. Our cyber research includes investments in providing a testing and evaluation environment for the experimentation and testing of cyber technology across the full spectrum of capabilities to help validate and accelerate research. Additionally, and very importantly, it is a priority for the DoD to be an early adopter of emerging technologies in cyber defense and to ensure the transition of those products to our warfighters and the programs supporting them.

Though challenges remain in all areas, Cyber S&T is making progress and having significant impacts. Over the past few years, our cyber investments, from fundamental research through advanced technology demonstrations have resulted in many successes that directly benefit our warfighters and the broader defense enterprise. Some highlights are:

- Securing our telecommunications infrastructure through vulnerability assessment, tool development, and best practice dissemination;
- Developing technologies to accurately geo-locate illicit commercial wireless devices to protect our networks;
- Producing a game-changing approach to signature-free malware detection capable of defending against zero-day attacks;
- Designing a flexible, mission-based interoperability framework enabling rapid, low-cost capability integration for our cyber operation forces; and
- Developing tools and techniques that assure the secure operation of microprocessors within our weapons platforms and systems.

This year, in concert with White House Priorities[12], we created the Cyber Transition to Practice (CTP) Initiative. The goal of this initiative is to mature and ultimately transition S&T products to operational use. The development of cyber tools frequently happens on a time scale much less than the traditional acquisition process. The CTP initiative is intended to accelerate fielding of cyber tools.

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[12] This is in direct response to the NSS Cybersecurity FY2014 Budget Priority of September 11, 2012 (section 4.a of the annex).

Loss of Assured Space. Other nations have developed both kinetic and non-kinetic means to degrade or deny the US space layer. Consequently, the DoD S&T program is working on developing the space capabilities our forces rely on whether or not the space layer exists. The capability may be degraded, but will also not be vulnerable. Other nations are seeking to asymmetrically disrupt our military capabilities that depend upon assured satellite communications; global systems for positioning, navigation, and timing; and on-demand ISR, even in denied areas. The US will respond to these actions through increasing the resilience of our space assets so they are free from interference as well as develop alternative means to deliver the capabilities we currently obtain from our space assets.

Current technologies in development include, but are not limited to the following: improving our space situational awareness capabilities employing improved ground- and space-based systems (such as the Air Force Research Lab's 2006 demonstration of on-orbit, localized Space Situational Awareness), enhanced terrestrial and airborne communications or jam resistant communications (such as laser communications); novel timing devices decoupled from continuous access to GPS (like the Tactical Grade Atomic Clock, projected for transition to the acquisition community in 2017); high performance Inertial Measurement Units (like DARPA's High Dynamic Range Atom Sensor (HiDRA), projected for 2016, and small-form-factor anti-jam GPS antennas); and alternative ISR capabilities (which may incorporate advanced electro-optic coatings and thermal protections measures under development at the Air Force Research Lab). Finally, we have several Joint Capability Technology Demonstrations (JCTDs) to determine the viability of capabilities delivered from very small satellites. Kestrel Eye and Vector JCTDs will demonstrate the viability of small satellite tactical communications and ISR by 2016.

Electronic warfare (both attack and protection). The Department's investment in electronic warfare (EW) S&T is about $500 million per year. This is an area that is evolving rapidly because of technology advances. The two key parameters in EW are the frequency the system operates and how complex is the signal. The concept behind electronic warfare is simple—the goal is to control your electronic signature or confuse an opponent's system if you are defending and to simplify the overall situation (reject false targets and clutter) if you are attempting to use your own electronic systems (radar, communications and radio frequency).

Electronic warfare is becoming important and more critical because the enabling technologies underlying frequency and complexity are progressing very rapidly. To address the underlying technologies, the components have coalesced around a concept called Advanced Components for EW (ACE), which is focusing on Integrated Photonic Circuits, Millimeter Wave, Electro-Optical and Infrared (EO/IR), and Reconfigurable and Adaptive RF electronics. As a whole, these technologies should improve simultaneous transmit and receive; expand instantaneous bandwidth, and allow a huge leap ahead in complexity. ACE kicked off in FY 2013, with the components continuing to develop components.

In addition to the underlying technology, the Services are involved in building advanced electronic systems. We will cover two of them. The Navy's Integrated Topside program is just completing attempting to use multifunction transmitters on the top of a ship. This will reduce the number of individual systems with a unique electronic signature, and improve ship survivability.

The Home on GPS-Jam (HOG-J) is a small munition that will identify foreign GPS jammers and vector the munition into the jammer. HOG-J has had some preliminary successful tests, and could be ready to enter the inventory in 2-3 years. There are other EW systems that could be covered at the appropriate security level.

Priority 2: Affordably Enabling New or Extending Military Capabilities

The cost of Defense acquisition systems continues to be a challenge for the Department. Over the past three years, the Department introduced "Better Buying Power" initiatives to improve the cost effectiveness of the Defense acquisition system. Cost effectiveness and affordability of defense systems starts before the acquisition enterprise kicks in. There are two vectors to increasing affordability; technology to lower cost and extend life cycle, and research and engineering processes to address costs early in system development.

Systems engineering. The Department's systems engineering capability and capacity are critical to enabling affordability across the system life cycle of an acquisition program. The Department's systems engineers drive affordable designs, develop technical plans and specifications to support cost-effective procurement, and conduct trade-off analyses to meet program cost, schedule and performance requirements. Systems engineers are enabling strategies to identify opportunities to reduce life-cycle costs. My organization has taken a lead role in improving the Department's ability to achieve affordable programs through strong SE policy, guidance, dissemination of best practices, execution oversight and support for a healthy, qualified engineering workforce.

Through an emphasis on affordability in recently updated policy and guidance, the Department has established a clear role for systems engineers in defining, establishing, and achieving affordability goals and processes throughout the life cycle. Through required systems engineering trade space analyses, individual acquisition programs establish the cost, schedule and affordability drivers and can demonstrate the cost-effective design point for the program. These trade space analyses will be conducted across the program's lifecycle to continuously assess system affordability and technical feasibility to support requirements, investments, and acquisition decisions and depict the relationships between system life-cycle cost and the system's performance requirements, design parameters, and delivery schedules. Recent emphasis on better reliability engineering has focused the Department's acquisition programs on reducing overall lifecycle costs. My systems engineering staff maintains regular and frequent engagement with acquisition programs to support the planning and execution of effective technical risk management, as well as affordability considerations. They provide regular oversight and guidance to assist the programs as they mature through the lifecycle.

Developmental Test and Evaluation. Developmental Test and Evaluation (DT&E) efforts focus on engaging major acquisition programs early in their lifecycle to ensure efficient and effective test strategies, thereby ensuring a better understanding of program technical risks and opportunities before major milestone decisions. In 2013, the Deputy Assistant Secretary of Defense for Developmental Test and Engineering (DASD(DTE)) introduced the "shift left" concept—specifically to drive DT earlier in the acquisition process. Early DT&E engagement with programs not only reduces acquisition costs through efficient testing, but finding and fixing

deficiencies early, well before production and operations, drastically reduces overall lifecycle costs. The DASD(DT&E) is focusing on a few key areas to improve the overall effectiveness of developmental test and evaluation; use of the Developmental Evaluation Framework, increased emphasis on testing in a mission context, earlier cyber security testing, and an increased emphasis on system reliability testing.

The Developmental Evaluation Framework is a disciplined process that results in a clear linkage between program decisions, capability evaluation, evaluation information needs, and test designs. Using the Developmental Evaluation Framework provides an efficient, yet rigorous T&E strategy to inform the program's decisions. Developmental Test and Evaluation is also moving beyond the traditional technical test focus to include testing in a mission context to characterize capabilities and limitations before production. Robust DT&E should also include early cyber security testing that previously was not tested until late in the acquisition life cycle, where deficiencies are costly to fix. Finally DT&E is focusing on increased system reliability testing. System reliability is a major driver in the affordability of future weapon systems. Improved reliability information early in the program allows acquisition leadership to understand the program technical and cost risks and take steps to improve system reliability and therefore the affordability of the system.

Prototyping. Another way to drive down costs of weapons systems is through the expanded use of prototypes, which we use to prove a concept or system prior to going to formal acquisition. Consequently, in FY 2015, we look to expand the use of developmental and operational prototyping to advance our strategic shift to a greater emphasis on future threats. In FY 2015, the Department's investment in prototypes or prototype like activities is around $900M. This includes activities that are not classical prototype efforts, but will demonstrate capabilities, such as the Navy's Future Naval Capabilities, Integrated Naval Prototypes, the Army's Joint Multi-role Helicopter and Future Fighting Vehicle, as well as Air Force Flagship programs, and the revamping of the Department's Joint Capability Technology Demonstrations and Emerging Capabilities Technology Development programs.

The RAND Corporation provides a good definition for prototyping, describing it as "a set of design and development activities to reduce technical uncertainty and to generate information to improve the quality of subsequent decision making."[13] We distinguish between two types of prototyping activities. Developmental prototyping demonstrates feasibility of promising emerging technologies and helps those technologies overcome technical risk barriers. Operational prototyping focuses on assessing military utility and integration of more mature technologies.

A recent example of an operational prototype is Instant Eye, a one pound quad-copter. We outfitted Instant Eye with an electro-optical camera and IR illuminator, bringing a field repairable, overhead surveillance capability to the soldier in the field at a unit cost of less than $1,000. Instant Eye would go on to provide targeting information for the neutralization of seven insurgents waiting to ambush a U.S. combat patrol.

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[13] "From Marginal Adjustments to Meaningful Change",pg 64, Jeffrey Drezner and Meilinda Huang, RAND Corporation, 2010

Joint Multi-Effects Warhead System (JMEWS) is a good example of a higher-risk, higher reward developmental prototype. The JMEWS project took on the challenge of in-flight targeting and re-tasking of the Tomahawk Land Attack Missile (TLAM). JMEWS' flexible lethality increases the combat power of these expensive weapons by tailoring the TLAM flight profile for best effect, taking advantage of information often not available until after the weapon has launched. With the developmental prototyping effort demonstrating the essential technical aspects, all that remains for Navy is to integrate JMEWS into the TLAM program of record.

Throughout the history of the Department, periods of fiscal constraint have been marked by the use of prototypes to mature technology and keep design teams active in advancing the state of practice. We will use prototyping to demonstrate capability early in the acquisition process. Prototyping will also be used to improve capability development methods and manufacturing techniques, evaluate new concepts, and rapidly field initial quantities of new systems. Prototyping's ability to evaluate and reduce technical risk, and clarify the resource picture that drives costs makes it a critical piece of the larger research and engineering strategy. Put simply, by prototyping in research and engineering, we can focus on key knowledge points and burn down the risk before the risk reduction becomes expensive.

Energy and power. Energy and Power Technology has a strong focus of reducing DoD operational energy risks and costs. Power requirements of new DoD systems continue to grow every year, and energy is a major cost driver and logistic burden. The Department spends approximately $300M per year on Energy and Power science and technology. Some significant programs are:

Unmanned Underwater Vehicles – Air Independent Propulsion (UUV-AIP). The Navy program is developing and delivering long endurance, scalable air-independent propulsion solutions for UUVs. Highly efficient fuel cell technologies will provide extended mission duration in excess of 60 days, well beyond the current and projected capability of batteries. Fuel cells are also being assessed by other Services to extend duration of UAVs and UGVs. These systems are already spinning out to industry.

The Integrated Vehicle Energy Technology (INVENT). The Air Force INVENT program is developing power and thermal management technologies and architectures that not only address today's aircraft performance limits but also work with adaptive cycle engines to enable next generation game changing high power airborne capabilities. There are related Service initiatives to realize higher performance, more fuel efficient designs for rotorcraft and ground vehicles.

Advanced Vehicle Power Technology Alliance (AVPTA). The Army is working collaboratively with DoE (with secondary partners from the National Labs, industry and academia) to accelerate energy-related R&D initiatives into new vehicle designs. Current efforts include: (1) advanced combustion, engines and transmission with the help of Sandia National Laboratory; (2) examination of lightweight structures for vehicles (partnering with General Dynamics); (3) energy recovery and thermal management for improved efficiency and reduced emissions (industry partner, Gentherm); (4) advanced fuels and lubricants; (5) integrated starter-generators (ISGs) without rare earth permanent magnet materials (partners, Remy Intl and Oak

Ridge National Laboratory); and (6) computer-aided engineering for electric drive batteries (CAEBAT).

Engineered Resilient Systems. To address the need for more affordable and mission-resilient warfighting systems, we are developing an integrated suite of modern computational modeling and simulation (M&S) capabilities and engineering tools aligned with acquisition and operational business processes to transform engineering environments under the Engineered Resilient Systems (ERS) initiative. The ERS tool suite allows warfighters, engineers, and acquisition decision-makers to rapidly assess the cost and performance of potential system designs by providing many data-driven alternatives resulting in systems which are less sensitive to changes in external threats, mission needs, and program constraints. ERS has already demonstrated that the insertion of advanced S&T models, tools and techniques into early phases of engineering processes and decision-making will positively impact effectiveness, affordability and sustainability of defense systems, thus addressing these most critical challenges head on. These new M&S-based frameworks adopt the most advanced design and modeling approaches of government, industry and academia to enable our Nation to meet emergent threat, while insuring that we can do that affordably, today and in an uncertain future.

Priority 3: Creating Technology Surprise Through Science and Engineering

The third and final reason the Department conducts research and engineering is to create surprise to potential adversaries. Previous Department of Defense investment in basic and applied research has a long history of developing technologies that led to superior capabilities. The DoD research program led to stealth, the internet, synthetic aperture radar, precision weapons, infra-red focal planes and night vision devices, among others. Frequently, when investing in basic research, we don't know the specific application that will emerge; in fact, by definition, basic research is conducted without a specific product or system in mind.

The Department invests in a structured way to create surprise. Creation of surprise requires a robust basic research program coupled with a strong applied research. While it is not really possible to know where technology surprise will come from, there are several areas that highlight the possibility; we will discuss several of them in increasing level of maturity. The least mature is quantum science, followed by nanotechnology, autonomous systems, human systems, and then finally, directed energy systems.

Quantum Sciences: The discoveries a century ago of the quantum properties of the atom and the photon defined and propelled most of the new technology of the 20th century – semiconductors, computers, materials, communication, lasers – the technological basis of much of our civilization. Now, the next quantum revolution may define new technological directions for the 21st century, building upon the intersection of quantum science and information theory. Consequently, the DoD is increasing its basic research investment in Quantum Information Science (QIS). QIS exploits our expanded quantum capabilities in the laboratory to engineer new properties and states of matter and light literally at the atomic scale. We are already developing new capabilities in secure communication, ultra-sensitive and high signal to noise physical sensing of the environment, and a path to exponentially faster computing algorithms in special purpose computers. The DoD research funding has driven quantum sciences in the past

decade. This funding has led to the demonstration to measure time through cold atom research at 1000 times more accurate than GPS. Using quantum sciences, the DoD is likely within 10 years of fielding an affordable timekeeping system that will cut our tether to GPS. We are building in the laboratory gravity sensors of unprecedented sensitivity, opening the possibility of remote detection of tunnels (or submarines). Other military applications are just being realized, but quantum science is a technology that will provide surprise.

Nanoengineering/Nanotechnology: QIS is based on the ability to control atoms. Nanoengineering also deals with the ability to develop and engineer systems at the molecular level. This will, in turn, lead to new system level capabilities. For instance, one of the limitations to systems like directed energy is thermal management. By designing systems at the molecular level, it is possible to increase thermal management by several orders of magnitude. Materials like "metamaterials" (engineered materials for specific properties) provide a promise of development of radars and electromagnetic systems that operate much more effectively at much broader frequency ranges. Metamaterials are especially intriguing because through clever design and dissimilar materials integration, properties that are never seen in nature's materials may be obtained. An example from the Navy's fundamental research realm is the investigation of a metamaterial suitable for antennas. This material system could become transparent to radio frequency waves when exposed to high power radio frequency radiation or pulses, preventing the coupling of this energy to an aircraft's electronic systems and, thereby, avoiding damage. Engineered nanomaterials and nanotechnology research remain very competitive in our research portfolio for their potential to provide capability advantage. Both the Navy and Army have explored coatings based on materials with nanometer dimensions that have wear and corrosion resistance superior to traditional and often hazardous metals. Most recently a nanocrystalline coating based on nickel-tungsten alloys has demonstrated properties exceeding hard chromium coatings without the potential environmental problems of chromium. One of the most exciting applications for engineered nanomaterials for defense and the whole economy is catalysts. The Air Force is supporting research on nanoparticle catalysts that are much more efficient in eliminating methane, a greenhouse gas, from exhausts while using the same quantity of the precious metal palladium and the rare earth element cerium. Energetic nanomaterials comprise one area of nanotechnology that is of interest primarily to defense at this time. The Army is examining highly reactive, energetic materials based on metals and metal oxides that are much less sensitive that traditional explosives. Because the DoD is committed to prudent development and application of new materials, we are studying the materials for any potentially unusual toxic properties based on their chemistry or extremely small particle size.

Autonomy: A major cost driver to the Department of Defense is the force structure but, technology is maturing to augment the human, possibly keeping the warfighter out of harm's way and reducing the numbers of warfighters needed to conduct operations. Autonomous capabilities range from software to aid the intelligence analyst in processing exploitation dissemination (PED) through very complex networked autonomous air systems working in tandem with unmanned ground or undersea vehicles. We could field simple autonomous systems within a couple of years, but true autonomy will take years to realize. Autonomous systems are truly multidisciplinary, in that they rely on technologies ranging from sensors that understand the environment, to software algorithms that aid decision making or decide to seek human assistance. Through autonomy, we seek to reduce the manpower required to conduct

missions, while extending and complementing human capabilities. The Department has four technical areas of focus for investments in Autonomy: Human and Agent System Interaction and Collaboration; Scalable Teaming of Autonomous Systems; Machine perception, Reasoning and Intelligence; and Test, Evaluation, Validation, and Verification. Built around these four technical areas, we launched an experiment last year to develop an in-house capacity in autonomous systems. This experiment, called the Autonomy Research Pilot Initiative (ARPI), funded seven proposals to work on technologies in one of the four technical areas above. The awards were for three years, and had to be completed in DoD laboratories by DoD personnel. ARPI efforts include: Autonomous Squad Member--enabling robots to participate in squad-level missions alongside soldiers; and Realizing Autonomy via Intelligent Adaptive Hybrid Control--increasing robustness and transparency of autonomous control to improve teaming of unmanned vehicles with each other and with their human operators. Advancement of technologies from the successful Department investment in the four technical areas will result in autonomous systems that provide more capability to warfighters, reduce the cognitive load on operators/supervisors, and lower overall operational cost.

Human Systems: Previous wars were won by massing power through weapons systems. It is not clear that will be the case in future conflicts. With the proliferation of sensors and data, future conflicts may well be won by the person that can react quickest. Studies of human cognition suggest that cognitive response times can be reduced by using display systems that present information using multiple sensory modalities. Such a reduction would give the force that is enabled with these technologies the ability to process more information, faster than their adversaries. Additionally, we are learning how to tailor training to adapt to individual students' unique needs, leading to reductions in the time needed to acquire expertise. Reducing the time to train forces to an advanced level of competence offers another way to respond faster than our adversaries. Additionally, robots, unmanned vehicles and other advanced technologies continue to be deeply integrated with our warfighters. We are developing new methodologies and technologies to enable our warfighters to interact with these systems as naturally as they do with their human counterparts leading to faster and more accurate responses by these "hybrid teams". Lastly, we are optimizing warfighter physical and cognitive performance for long durations, in dynamic and unpredictable environments, through personalized conditioning and nutritional regimens.

Directed Energy: One of the most mature "game changing" technology areas is Directed Energy, and specifically, High Energy Lasers. High Energy Lasers have been promised for many years, but these lasers were always based on chemical lasers, which are difficult to support logistically, and the byproducts are toxic. Over the past several years, however, solid state (electric) lasers have matured, largely through the Joint High Power Solid State Laser, a cross DoD effort to develop a 100 kilowatt (KW) laser. At close range, 10-30 KW is lethal. The JHPSSL was demonstrated in 2009. Since then, the Services have worked on packaging a solid state laser that could be deployed. In Summer 2014, a 30 KW laser will be prototyped on the USS Ponce in the CENTCOM area of responsibility. In December 2013, the Army demonstrated the High Energy Laser Mobile Demonstrator at White Sands missile range. This 10 KW laser successfully engaged nearly 90% of the available targets. This system will be further demonstrated in a maritime environment at Eglin Air Force Base.

RELIANCE 21

The Department's Research and Engineering (R&E) Enterprise is wide-ranging, and is the foundation of the Department's technological strength. The enterprise includes DoD laboratories and product centers, other government laboratories, federally funded research and development centers (FFRDC's) and University affiliated research centers (UARCs), US and allied universities, our allied and partner government laboratories, as well as industry. Last year I took the opportunity to brief the members of this Committee as my impetus to develop a strategy for the R&E Enterprise; this strategy was discussed earlier. What is important this year is putting in place the structure to attempt to optimize the S&T investment. Consequently, the Department's S&T Executives and I have worked to put in place Reliance 21. Under Reliance 21, most of the Department's S&T program will be managed in one of 17 cross-cutting portfolios. Each of these portfolios will be made up of Senior Executive or Senior Leader from each Service and Agency with investment in the area. These teams are building integrated roadmaps, and beginning the process of integrating allied and industry efforts onto our roadmaps. Each year, about one third of the portfolios will be reviewed, in depth to the S&T Executives, who will approve or redirect the roadmaps. The roadmap will include the technical and operational objective, the critical technical efforts needed to meet the objective, the gaps to reaching the objectives, and an assessment of where the portfolio leads recommend changes. The 17 portfolios are all called Communities of Interest (COI). Done correctly, management of a large portion of the Department's S&T execution will be collaboratively achieved by the COIs.

What Congress can do for the Defense S&T Program

We are the most technologically advanced military in the world but, as Secretary Hagel so aptly stated in his remarks on the 24th of February of this year, "we must maintain our technological edge over potential adversaries"[14]. I have outlined what we are doing with the resources that we have been given and what we plan to do with the resources in the FY 2015 President's budget. Success, however, will depend on your support. In that regard I have two requests.

I ask that you enact the Research, Development, Test and Evaluation portion of the President's Budget as submitted. We spent a lot of time to balance the program to best meet DoD priorities.

The President's Budget seeks funding for FY 2016-2021 that is above the estimated sequestration levels under current law. As pointed out earlier, with no relief from the BCA in the out years, we expect modernization and readiness accounts to bear the brunt. This would heighten the increased risk we are already seeing. Simply, at that sequestration level, we expect continued erosion of the S&T and RDT&E accounts.

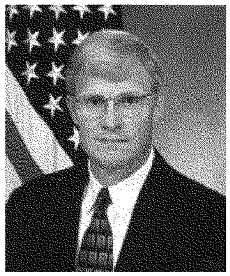
Second, I would ask that you support our efforts in prototyping. We are expanding the use of developmental and operational prototyping in lieu of formal acquisition programs. Throughout the history of the Department, during periods of fiscal constraint, the Department has used prototypes to mature technology and keep design teams intact and moving forward.

[14] Hagel, 24 February 2014.

Prototyping has another advantage—it allows the Department to build a capability early in the acquisition process, before all the structure affiliated with the acquisition process begins. By prototyping in research and engineering, we can acquire valuable knowledge and buy down risk and lead time to production at relatively low cost.

CLOSING

In summary, the last year has been a challenge to the Department's S&T program. The risk to our force is growing, and the need for the S&T community is likewise increasing. We have shifted our focus to protecting the future by countering anti-access, area-denial threats, addressing the increasing complexity of adversary's weapons systems, shortening the maturation time of developing our own systems, and addressing the erosion of the United States' stature in international science markers. We need your help to remove the crippling uncertainty associated with sequestration so that we can transition to the balance of force structure, readiness and modernization the country needs and deserves from us.



Mr. Alan R. Shaffer
Principal Deputy, Assistant Secretary of Defense for Research and Engineering

Mr. Shaffer serves as the Principal Deputy, Assistant Secretary of Defense for Research and Engineering. In this position, Mr. Shaffer is responsible for formulating, planning, and reviewing the DoD Research, Development, Test, and Evaluation (RDT&E) programs, plans, strategy, priorities, and execution of the DoD RDT&E budget. Specifically, this position reviews the maturity of technology as part of the acquisition cycle, as well as develops options to reduce the overall technology development risk to DoD programs.

Prior to entering the federal government, Mr. Shaffer served a 24-year United States Air Force career with assignments in weather, intelligence, science and technology management, acquisition oversight, and programming. His career included deployment to Honduras in support of Joint Task Force Bravo in the mid-1980s and direct support of the United States Army 3rd Armored Division at Hanau, Germany. During Operation DESERT STORM, he was responsible for deployment of the 500-person theater weather force. Other assignments included Wing Weather Officer supporting the 320th Bombardment Wing (Heavy) at Mather AFB, California; Intelligence Officer at Foreign Technology Division, Wright Patterson AFB, OH; Deputy Director of Weather for Air Combat Command, Langley AFB, VA, numerous staff assignments in the Air Staff and Office of the Secretary of Defense, in the Pentagon; and finally, the Air Force Weather Agency, Offutt AFB, Nebraska.

Upon retirement from the United States Air Force in 2000, Mr. Shaffer was appointed to the Senior Executive Service as the Director, Multi-disciplinary Systems, Office of the Deputy Under Secretary of Defense for Science and Technology. In 2001, he assumed the position as Director, Plans and Programs, Defense Research and Engineering. Mr. Shaffer continues to serve as the Director while serving as the Principal Deputy. As the Director for Plans and Programs, Mr. Shaffer is responsible for the oversight of the Department of Defense science and technology portfolio totaling over $10.5 billion. Mr. Shaffer has served as the Executive Director for several senior Task Forces. These included the Technical Joint Cross Service Group during the Base Realignment and Closure activity; DoD Energy Security Task Force in 2007and most recently the Executive Director of the Mine Resistant Ambush Protection Task Force. In addition he serves as the tri-chair to the Department of Defense Modeling and Simulation Steering Committee.

Mr. Shaffer earned a Bachelor of Science Degree in Mathematics from the University of Vermont in 1976. He earned a second Bachelor of Science in Meteorology from the University of Utah, a Master of Science in Meteorology from the Naval Postgraduate School, and a Master of Science in National Resource Strategy from the Industrial College of the Armed Forces. He has been awarded the Distinguished Executive Presidential Rank Award in 2007 and the Meritorious Executive Presidential Rank Award in 2004.

STATEMENT BY
MS. MARY J. MILLER

DEPUTY ASSISTANT SECRETARY OF THE ARMY

FOR RESEARCH AND TECHNOLOGY

BEFORE THE

INTELLIGENCE, EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

OF THE

HOUSE ARMED SERVICES COMMITTEE

ON

THE UNITED STATES ARMY'S SCIENCE AND TECHNOLOGY (S&T)

PROGRAM FOR FISCAL YEAR 2015

SECOND SESSION, 113TH CONGRESS

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BY THE COMMITTEE ON ARMED SERVICES

UNITED STATES HOUSE OF REPRESENTATIVES

STATEMENT BY
MS. MARY J. MILLER

DEPUTY ASSISTANT SECRETARY OF THE ARMY

FOR RESEARCH AND TECHNOLOGY

Mr. Chairman, Ranking Member Langevin, and distinguished members of the Subcommittee, thank you for the opportunity to discuss the Army's Science and Technology (S&T) Program for fiscal year (FY) 2015.

> *"Over the past 12 years of conflict, our Army has proven itself in arguably the most difficult environment we have ever faced. Our leaders at every level have displayed unparalleled ingenuity, flexibility and adaptability. Our Soldiers have displayed mental and physical toughness and courage under fire. They have transformed the Army into the most versatile, agile, rapidly deployable and sustainable strategic land force in the world."*[1]
>
> *— Sec John W. McHugh, Gen Raymond T. Odierno*

After twelve years of persistent conflict, the United States finds itself in a familiar situation — facing a declining defense budget and a strategic landscape that continues to evolve. As our current large-scale military campaign draws down, the United States still faces a complex and growing array of security challenges across the globe as "wars over ideology have given way to wars over religious, ethnic, and tribal identity; nuclear dangers have proliferated; inequality and economic instability have intensified; damage to our environment, food insecurity, and dangers to public health are increasingly shared; and the same tools that empower individuals to build enable them to destroy."[2] Unlike past draw downs, where the threats we faced were going away, there remain a number of challenges that we still have to confront -- challenges that call for a change in America's defense priorities. Despite these challenges, the United States Army is committed to remaining capable across the spectrum of operations. While the future force will become smaller and leaner, its great

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[1] The Posture of the United States Army, Committee on Armed Services, United States House of Representatives, April 23, 2013.

[2] National Security Strategy, May 2010.

strength will lie in its increased agility, flexibility, and ability to deploy quickly, while remaining technologically advanced. We will continue to conduct a complex set of missions ranging from counterterrorism, to countering weapons of mass destruction, to maintaining a safe, secure and effective nuclear deterrent. We will remain fully prepared to protect our interests and defend our homeland.[3]

The Army depends on its Science and Technology (S&T) program to help prepare for the future, mitigate the possibility of technical surprise and ensure that we remain dominant in any environment. The Army's S&T mission is to foster discovery, innovation, demonstration and transition of knowledge and materiel solutions that enable future force capabilities and/or enhance current force systems. The Army counts on the S&T Enterprise to be seers of the future – to make informed investments now, ensuring our success for the future.

The Army is ending combat operations in Afghanistan and refocusing on the Asia-Pacific region with greater emphasis on responses to sophisticated, technologically proficient threats. We are at a pivotal juncture – one that requires us to relook the past twelve years of conflict and capitalize on all the lessons that we have learned, while we implement a strategic shift to prepare for a more capable enemy. As the Department of Defense prepares for the strategic shift, the Army will adapt — remaining an ever present land force — unparalleled throughout the World.

We are grateful to the members of this Committee for your sustained support of our Soldiers, your support of our laboratories and centers and your continued commitment to ensure that funding is available to provide our current and future Soldiers with the technology that enables them to defend America's interests and those of our allies around the world.

Strategic Landscape

As we built the FY15 President's Budget Request, the Army faced a number of significant challenges. While the Army has many priorities, the first and foremost priority is and always will be to support our Soldiers in the fight. We are pulling our troops and equipment out of Afghanistan by the end of this December, we are drawing down our force structure, we are resetting our equipment after 12 plus years of war and we are trying to modernize. Given the budget downturn within the Department of Defense, the Army has been forced to face some

[3] "The Posture of the United States Army," The Honorable John M. McHugh, Secretary of the Army and General Raymond T. Odierno, Chief of Staff, United States Army before the Senate Committee on Appropriations, Subcommittee on Defense, May 22, 2013.

difficult choices. The Army is in the midst of a significant force structure reduction – taking the Army to pre-World War II manning levels. The Chief of Staff of the Army has undertaken difficult decisions balancing force structure, operational readiness, and modernization to maintain a capable force able to prevent, shape and win in any engagement. As a result, over the next five years, we face a situation where modernization will be slowed, new programs will not be initiated as originally envisioned and the Army's S&T Enterprise will be challenged to better prepare for the programs and capabilities of the future. We will focus on maturing technology, reducing program risk, developing prototypes that can be used to better define requirements and conducting experimentation with Soldiers to refine new operational concepts. The S&T community will be challenged to bring forward not only new capabilities, but capabilities that are affordable for the Army of the future.

> *"Going forward, we will be an Army in transition. An Army that will apply the lessons learned in recent combat as we transition to evolving threats and strategies. An Army that will remain the best manned, best equipped, best trained, and best led force as we transition to a leaner, more agile force that remains adaptive, innovative, versatile and ready as part of Joint Force 2020."*[4]
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> — *General Raymond T. Odierno, 38th Chief of Staff, Army*

Goals and Commitments

The emerging operational environment presents a diverse range of threats that vary from near-peer to minor actors, resulting in new challenges and opportunities. In this environment, it is likely that U.S. forces will be called upon to operate under a broad variety of conditions. This environment requires a force that can operate across the range of military operations with a myriad of partners, simultaneously helping friends and allies while being capable of undertaking independent action to defeat enemies, deter aggression, and shape the environment. At the same time, innovation and technology are reshaping this environment, multiplying and intensifying the effects that even minor actors are able to achieve.

The Army's S&T investment is postured to address these emerging threats and capitalize on opportunities. The S&T investment continues to not only focus on developing more capable and affordable systems, but also on understanding the complexity of the future environment. We have focused on assessing technology

[4] "Marching Orders," General Raymond T. Odierno, 38th Chief of Staff, U.S. Army, January 2012.

and system vulnerabilities (from both a technical and operational perspective) to better effect future resilient designs and to prepare countermeasures that restore our capabilities when necessary.

There are persistent (and challenging) areas where the Army invests its S&T resources to ensure that we remain the most lethal and effective Army in the world. As the Army defines its role in future conflicts, we are confident that these challenges will remain relevant to the Army and its ability to win the fight. The S&T community is committed to help enable the Army achieve its vision of an expeditionary, tailorable, scalable, self-sufficient, and leaner force, by addressing these challenges:

- Enabling greater *force protection* for Soldiers, air and ground platforms, and bases (e.g., lighter and stronger body armor, helmets, pelvic protection, enhanced vehicle survivability, integrated base protection)
- *Easing overburdened* Soldiers in small units (both cognitive and physical burden, e.g., lighter weight multi-functional materials)
- Enabling *timely mission command and tactical intelligence* to provide situation awareness and communications in ALL environments (mountainous, forested, desert, urban, jamming, etc.)
- *Reducing logistic burden* of storing, transporting, distributing and retrograding materials
- Creating operational overmatch (*enhancing lethality and accuracy*)
- Achieving *operational maneuverability* in all environments and at high operational tempo (e.g., greater mobility, greater range, ability to operate in high/hot environments)
- Enabling *early detection and treatment for* Traumatic Brain Injury *(TBI) and* Post Traumatic Stress Disorder *(PTSD)*
- *Improving operational energy* (e.g., power management, micro-grids, increased fuel efficiency engines, higher efficiency generators, etc.)
- Improving *individual and team training* (e.g., live-virtual-constructive training)
- *Reducing lifecycle costs* of future Army capabilities

In addition to these enduring challenges, the S&T community conducts research and technology development that impacts our ability to maintain an agile and ever ready force. This includes efforts such as establishing environmentally compatible installations and materiel without compromising readiness or training, creating leader selection methodologies, and new test tools that can save

resources and reduce test time, and establishing methods and measures to improve Soldier and unit readiness and resilience.

The Army S&T strategy acknowledges that we must respond to the new fiscal environment and changing technology playing field. Many critical technology breakthroughs are being driven principally by commercial and international concerns. We can no longer do business as if we dominate the technology landscape. We must find new ways of operating and partnering. We realize that we should invest where the Army must retain critical capabilities but reap the benefits of commercially driven technology development where we can. No matter the source, we will ensure the Army is aware of the best and most capable technologies to enable a global, networked and full-spectrum joint force in the future. As the U.S. rebalances its focus by region and mission, it must continue to make important investments in emerging and proven capabilities. **In a world where all have nearly equal access to open technology, innovation is the most important discriminator in assuring technology superiority.**

The Chief of Staff of the Army has made his vision clear.

> *"The All-Volunteer Army will remain the most highly trained and professional land force in the world. It is uniquely organized with the capability and capacity to provide expeditionary, decisive landpower to the Joint Force and ready to perform across the range of military operations to Prevent, Shape, and Win in support of Combatant Commanders to defend the Nation and its interests at home and abroad, both today and against emerging threats.[5]"*
>
> *— General Raymond T. Odierno, 38th Chief of Staff, Army*

The Army is relying on its S&T community to carry out this vision for the Army of the future.

Implementing New Processes

Turning science into capability takes a continuum of effort including fundamental research, the development and demonstration of technology, the validation of that technology and its ultimate conversion into capability. From an S&T materiel perspective, this includes the laboratory confirmation of theory, the demonstration of technical performance, and the experimentation with new technologies to identify potential future capabilities and to help refine/improve system designs. But the S&T Enterprise is also charged with helping to

[5] Gen Raymond Odierno, 38th Chief of Staff Army, "CSA Strategic Priorities, Waypoint 2", 2014

conceptualize the future -- to use our understanding of the laws of physics and an ability to envision a future environment to broaden the perspective of the requirements developers as well as the technology providers.

As part of this continuum, the Army has adopted a 30 year planning perspective to help facilitate more informed program planning and budget decisions. A major part of the S&T strategy is to align S&T investments to support the acquisition Programs of Record (PoRs) throughout all phases of their lifecycle and across the full DOTMLPF (Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities). By expanding the perspective, areas where there are unaffordable alignments of activities (such as multiple major Engineering Change Proposals in the same portfolio within the same 2-3 year timeframe) or unreasonable alignments (such as planned technology upgrades to a system that has already transitioned into sustainment) are made obvious. With that information in mind, the Army has established “tradespace” to generate options that inform strategic decisions that allow the Army to stay within its fiscal top line while maximizing its capabilities for the Warfighter.

This new and ongoing process, known as the Long Range Investment Requirements Analysis (LIRA), has put additional rigor into the development of the Army’s budget submission and creates an environment where the communities who invest in all phases of the materiel lifecycle work together to maximize the Army’s capabilities over time. From an S&T perspective, it clearly starts to inform the materiel community as to WHEN technology is needed for insertion as part of a planned upgrade. It also cues us as to when to start investing for replacement platforms. In addition, this long-range planning can introduce opportunities for convergence of capabilities such as the development of a single radar that can perform multiple functions for multiple platforms or the convergence of cyber and Electronic Warfare (EW) capabilities into one system. Aside from the obvious benefit achieved by laying out the Army’s programs and seeing where we may have generated unrealizable fiscal challenges, it has reinvigorated the relationships and strengthened the ties between the S&T community and their Program Executive Office (PEO) partners. We are working together to identify technical opportunities and the potential insertion of new capabilities across this 30 year timeframe.

The LIRA process was used to inform the development of the FY15 President’s Budget. As the Army faced a dramatic decline in its modernization accounts (a 40% decrement over the next two years), we used the results of the LIRA to ensure that we had a fiscally sound strategy.

The S&T Portfolio

The nature of Science and Technology is such that continuity and stability have great importance. Starting and stopping programs prevents momentum in research and lengthens the timelines for discovery and innovation. While the Army S&T portfolio gains valuable insight from the threat community, this only represents one input to the portfolio and likely describes the most probable future. To have a balanced outlook across all the possible futures requires that the portfolio also address the "possible" and "unthinkable." The Army's S&T portfolio is postured to address these possible futures across the eight technology portfolios identified Figure 1.

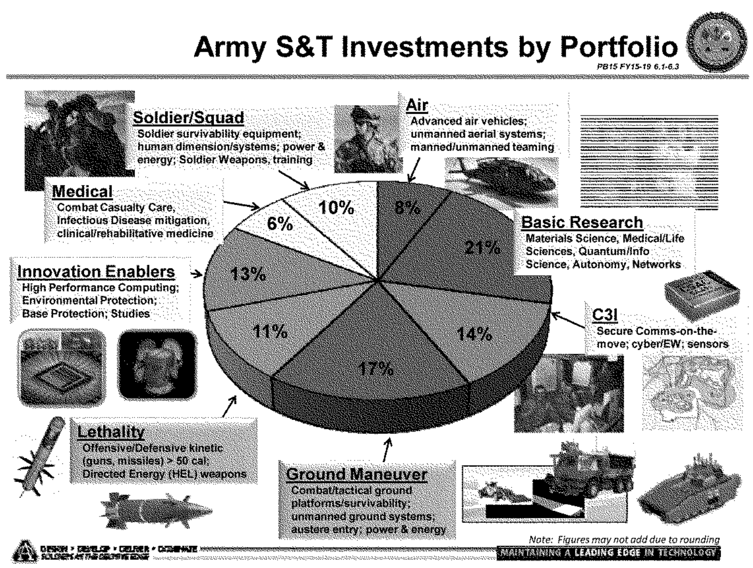

Figure 1. Army S&T Investments by Portfolio

The efforts of the S&T Enterprise are managed by portfolio to ensure maximum synergy of efforts and reduction of unnecessary duplication. The S&T program is organized into eight investment portfolios that address challenges across six Army-wide capability areas (Soldier/Squad; Air; Ground Maneuver; Command, Control, Communications, and Intelligence (C3I); Lethality; and Medical) and two S&T enabling areas (Basic Research and Innovation Enablers).

The 2014 Quadrennial Defense Review (QDR) protects and prioritizes key investments in technology to maintain or increase capability while forces grow leaner. This is an opportunity to look at innovative applications of technology. As a result, in the FY15 President's Budget Request, the Army is maintaining, and shifting where necessary, its emphasis on technology areas that enable the Army to be leaner, expeditionary, and more lethal.

We are now in an era of declining acquisition budgets and are mindful of the challenges this brings to our S&T programs. We will have fewer opportunities for transition to Programs of Record in the next few years. This "pause" in acquisition does however afford us the opportunity to further develop and mature technologies, ensuring that when acquisition budgets do recover, S&T will be properly positioned to support the Army's next generation of capabilities. This year finds the Army beginning to rebalance its S&T funding between Basic Research, applied research and advanced technology development. We appreciate the flexibility that was provided to the DoD S&T executives to better align our funding to our Service/Agency needs after years of proscriptive direction.

In FY15, our Advanced Technology Development investments increase to 42% of our $2.2B budget. This is a deliberate increase from previous years as the Army looks to its S&T community to conduct more technology demonstration/ prototyping initiatives that will inform future Programs of Record (PoRs). Specifically you will see the Army shifting or increasing emphasis on research areas that support the next generation of combat vehicles (including power and energy efficiency, mobility and survivability systems), Anti-Access/Area Denial (A2/AD) technologies such as assured Position Navigation and Timing (PNT) and austere entry capabilities, Soldier selection tools and training technologies, as well as long range fires. Two of these efforts, the Future Infantry Fighting Vehicle (FIFV) and the assured Position Navigation and Timing (PNT) efforts are being done in collaboration with the respective PEOs to ensure that the capability developed and demonstrated not only helps to refine the requirements for the future PoRs but establishes an effective link for transition. We are also increasing our investments in vulnerability assessments of both technology and systems as well as expanding our Red Teaming efforts to identify potential vulnerabilities in emerging technologies, systems and systems-of-systems, including performance degradation in contested environments, interoperability, adaptability, and training/ease of use. This year begins the re-alignment necessary to implement our strategy of investing in areas critical to the Army – areas where we have critical skills sets, and leveraging others (sister services, other government agencies, academia, industry, allies) for everything else.

We anticipate a future where rapidly advancing technologies such as autonomous systems, high yield energetics, immersive training environments, alternative power and energy solutions, and the use of smart phones and social media will become critical to military effectiveness. The Army will continue to develop countermeasures to future threat capabilities and pursue technological opportunities. Enemies and adversaries however, will counter U.S. technological advantages through cover, concealment, camouflage, denial, deception, emulation, adaptation, or evasion. Finally, understanding how humans apply technology to gain capabilities and train will continue to be at least as important as the technologies themselves.

We are mindful however that the Army will continue to be called on for missions around the globe. The Army is currently deployed in ~160 countries conducting missions that range from humanitarian support to stability operations to major theater warfare. As we have seen in the last month, the world is an unpredictable place, and our Soldiers must have the capabilities to deal with an ever changing set of threats.

S&T Portfolio Highlights

I'd like to highlight a few of our new initiatives and remind you of some of our on-going activities that will help frame the options for the Army of the future.

Soldier/Squad Portfolio

One of the important initiatives currently underway that we anticipate will make major inroads into our efforts to lighten the Soldier's load is the development of a Soldier Systems Engineering Architecture. This architecture, developed in concert with our acquisition and requirements community, is an analytical decision-based model through which changes in Soldier system inputs (loads, technology/equipment, physiological & cognitive state, stress levels, training, etc.) may be assessed to predict changes in performance outputs of the Soldier system in operationally relevant environments. By using a systems engineering approach, the model will result in a full system level analysis capable of predicting impacts of both materiel and non-materiel solutions on fully equipped Soldiers performing operational missions/tasks

In keeping with the CSA's vision, our S&T efforts also support the Army's training modernization strategy by developing technologies for future training environments that sufficiently replicate the operational environment. We are also developing new training effectiveness measures and methods, ensuring that these new training technologies can rapidly and effectively transfer emerging

warfighting experience and knowledge into robust capabilities. In addition, the need to reduce force structure has increased the importance of our research in the area of personnel selection and classification. This research will provide the Army with methods to acquire and retain candidates best suited for the Army – increasing our flexibility to adapt to changes in force size, structure and mission demands. Other important research includes developing scientifically valid measures and metrics to assess command climate and reduce conduct related incidences, including sexual harassment and assault in units to ensure the Army can maintain a climate of dignity, respect and inclusion.

Air Portfolio

As the lead service for rotorcraft, owning and operating over 80% of the Department of Defense's vertical lift aircraft, the preponderance of rotorcraft technology research and development takes place within the Army. Our key initiative, the Joint Multi-Role Technology Demonstrator (JMR TD) program, is focused on addressing the A2/AD need for longer range and more efficient combat profiles. As we shift to the Pacific Rim focus, future Areas of Operation (AO) may be sixteen times larger than those of our current AOs. The Army needs a faster, more efficient rotorcraft, capable of operating in high/hot environments (6000 feet and 95 degrees) with significantly decreased operating costs and maintenance required. The new rotorcraft will also require improved survivability against current and future threats. The goal of the JMR TD effort is to reduce risk for the Future Vertical Lift planned PoR, the Department of Defense's next potential "clean sheet" design rotorcraft. The overall JMR TD effort will use integrated government/industry platform design teams and exercise agile prototyping approaches. At the same time, the Army is collaborating with DARPA on their x-plane effort. While the DARPA program is addressing far riskier technologies that are not constrained by requirements, we will look to leverage technology advancements developed under the DARPA effort where possible.

Another initiative that we are beginning in FY15 is addressing one of the biggest causes of aircraft loss - accidents that occur while operating in a Degraded Visual Environments (DVE). DVE is much more than operating while in brown out – this effort looks at mitigating all sources of visual impairment, either those caused by the aircraft itself (brownout, whiteout) or other "natural" sources (rain, fog, smoke, etc.). We are currently conducting a synchronized, collaborative effort with PEO Aviation to define control system, cueing, and pilotage sensor combinations which enable maximum operational mitigation of DVE. This S&T effort will result in a prioritized list of compatible, affordable DVE mitigation technologies, and operational specification development that will help inform

future Army decisions. This program is tightly coupled with the PEO Aviation strategy and potential technology off-ramps will be transitioned to the acquisition community along the way, when feasible.

Ground Maneuver Portfolio

The Ground Maneuver Portfolio is focused on maturing and demonstrating technologies to enable future combat vehicles, including the Future Infantry Fighting Vehicle (FIFV). In FY15, you will see the beginning of a focused initiative done in collaboration with PEO Ground Combat Systems, to develop critical sub-system prototypes to inform the development and requirements for the Army's Future Infantry Fighting Vehicle (FIFV). These sub-system demonstrators focus on mobility (e.g., engine, transmission, suspension); survivability (e.g., ballistic protection, under-body blast mitigation, advanced materials); Active Protection Systems (APS); a medium caliber gun and turret; and an open vehicle power and data architecture that will provide industry with a standard interface for integrating communications and sensor components into ground vehicles.

Armor remains an Army-unique challenge and we have persistent investments for combat and tactical vehicle armor, focusing not only on protection but also affordability and weight reduction. We continue to invest in advanced materials and armor technologies to inform the next generation of combat and tactical vehicles.

In FY15, this portfolio continues its shift to focus to address A2/AD challenges. We've increased efforts on technologies to enable stand-off evaluation of austere ports of entry and infrastructure to better enable our ability to enter areas of conflict. We are also maintaining technology investments in detection and neutralization of mines and improvised explosive devices to ensure freedom of maneuver.

C3I Portfolio

The C3I portfolio provides enabling capability across many of the challenges, but specifically seeks to provide responsive capabilities for the future in congested Electro-Magnetic environments. These capabilities are supported by sustained efforts in sensors, communications, electronic warfare and information adaptable in dynamic, congested and austere (disconnected, intermittent and limited) environments to support battlefield operations and non-kinetic warfare. Renewed efforts in the C3I portfolio include reinvigorating efforts in sensor protection. We continue to invest in EW vulnerability analysis to perform characterization and analysis of radio frequency devices to develop detection and characterization

techniques, tactics, and technologies to mitigate the effects of contested environments (such as jamming) on Army C4ISR systems.

Given the potential challenges that we face while operating in a more contested environment, we are placing additional emphasis on assured Position, Navigation and Timing, developing technologies that allow navigation in Global Positioning System (GPS) denied/degraded environments for mounted and dismounted Soldiers and unmanned vehicles such as exploiting signals of opportunity. We will study improvements for high sensitivity GPS receivers that could allow acquisition and tracking in challenging locations such as under triple canopy jungles, in urban areas, and inside buildings. We are developing Anti-Jam capabilities as well as supporting mission command with interference source detection, signal strength measurement, and with locating interference sources, thereby enabling the Army to conduct its mission in challenging electromagnetic environments.

The C3I Portfolio also includes our efforts in cyber, both defensive and offensive. Defensive efforts in cyber security will investigate and develop software, algorithms and devices to protect wireless tactical networks against computer network attacks. We are developing sophisticated software assurance algorithms to differentiate between stealthy life cycle attacks and software coding errors, as well as investigating and assessing secure coding methodologies that can detect and self-correct against malicious code insertion. We will research and design sophisticated, optimized cyber maneuver capabilities that incorporate the use of reasoning, intuition, and perception while determining the optimal scenario on when to maneuver, as well as the ability to map and manage the network to determine probable attack paths and the likelihood of exploitation.

On the offensive side of cyber operations, we will develop integrated electronic attack (EA) and computer network operations hardware and software to execute force protection, EA, electronic surveillance and signals intelligence missions in a dynamic, distributed and coordinated fashion.

We will demonstrate protocol exploitation software and techniques that allow users to remotely coordinate, plan, control and manage tactical EW and cyber assets; develop techniques to exploit protocols of threat devices not conventionally viewed as cyber to expand total situational awareness by providing access to and control of adversary electronic devices in an area of operations.

Lethality Portfolio

In FY15, you will see continued emphasis on the development of A2/AD capabilities through Long Range Fires and Counter Unmanned Aircraft technologies. S&T is focusing on advanced seeker technologies to enable acquisition of low signature threats at extended ranges, along with dual pulse solid rocket motor propulsion to provide longer range rockets and extend the protected areas of air defense systems. To support these capabilities, we are conducting research in new energetic materials focused on both propulsive and explosive applications. These materials have significantly higher energetic yield than current materials and will increase the both effectiveness of our systems and reduce their size.

We also continue to develop Solid State High Energy Lasers to provide low cost defeat of rockets, artillery, mortars and unmanned aircraft. We have had multiple successes in High Energy Lasers, as we demonstrated successful tracking and defeat of mortars and unmanned aircraft in flight this year (FY14) from our mobile demonstrator.

Additionally, we are supporting the Ground Maneuver Portfolio in the demonstration of a medium caliber weapon system to enable Future Infantry Fighting Vehicle requirements for range and lethality including an airburst munition.

Medical

The Medical portfolio addresses the wellness and fitness of our Soldiers from accession through training, deployment, treatment of injuries and return to duty or to civilian life. Ongoing efforts address multiple threats to our Soldiers' health and readiness. Medical research focuses on areas of physiological and psychological health that directly support the Chief of Staff of the Army Ready and Resilience Campaign and the Army Surgeon General's Performance Triad (Activity, Nutrition and Sleep). Research in these portfolios includes important areas such as Traumatic Brain Injury (TBI) and Post Traumatic Stress Disorder (PTSD). In FY15, you will see continued focus on research to mitigate infectious diseases prevalent in the Far East as well as combat casualty care solutions at the point of injury that will extend Soldier's lives during the extended distances associated with conducting operations in the Pacific.

TBI research efforts include furthering our understanding of cell death signals and neuroprotection mechanisms, as well as identifying critical thresholds for secondary injury comprising TBI. The Army is also evaluating other non-traditional therapies for TBI, and identifying "combination" therapeutics that

substantially mitigate or reduce TBI-induced brain damage. Current Army funded research efforts in the area of PTSD are primarily focused upon development of pharmacologic solutions for the prevention and treatment of PTSD. A large-scale clinical trial is currently underway evaluating the effectiveness of Sertraline, one of two Selected Serotonin Reuptake Inhibitors (SSRIs) approved for the treatment of civilian PTSD, but not combat-related PTSD. This study will evaluate Sertraline's effectiveness in the treatment of combat-related PTSD both alone and in combination with psychotherapy.

Innovation Enablers

As the largest land-owner/user within the DoD, it is incumbent upon the Army to be good stewards in their protection of the environment. As such, the Army develops and validates lifecycle models for sustainable facilities, creates dynamic resource planning/management tools for contingency basing, develops decision tools for infrastructure protection and resiliency and assesses the impact of sustainable materials/systems on the environment.

In addition, we conduct blast noise assessment and develop mitigation technologies to ensure that we remain "good neighbors" within Army communities and work to protect endangered species while we ensure that the Army mission can continue.

The High Performance Computing (HPC) Modernization Program supports the requirements of the DoD's scientists and engineers by providing them with access to supercomputing resource centers, the Defense Research and Engineering Network (DREN) (a research network which matures and demonstrates state of the art computer network technologies), and support for software applications, including the experts that help to improve and optimize the performance of critical common DoD applications programs to run efficiently on advanced HPC systems maturing and demonstrating leading-edge computational technology.

The Army's Technology Maturation Initiatives effort, established in FY12 enables a strategic partnership between the S&T and acquisition communities. This effort has become especially important as the Army heads into a funding downturn. We plan to use these funds to prepare the Army to capitalize on S&T investments as we come out of the funding "bathtub" near the end of the decade. We are using these Budget Activity 4 resources to target areas where acquisition programs intended to provide necessary capabilities have been delayed, such as assured Position, Navigation and Timing (PNT), the Future Infantry Fighting Vehicle and Active Protection Systems. We are investing resources that will

either provide capability or inform/refine requirements for the Army's future systems (all of which will be done via collaborative programs executed with our acquisition/PEO partners).

This portfolio includes our ManTech efforts as well. Last month, President Obama announced the launch of the Digital Manufacturing and Design Innovation Institute (DMDI). Headquartered in Chicago, Illinois, and managed by the U.S Army's Aviation and Missile Research Development and Engineering Center, the DMDI Institute spearheads a consortium of 73 companies, universities, nonprofits, and research labs. The president announced a government investment of $70 million and matching private investments totaling $250 million for the institute. DMDI is part of the president's National Network of Manufacturing Innovation (NNMI) and will focus on the development of novel model-based design methodologies, virtual manufacturing tools, and sensor and robotics based manufacturing networks that will accelerate the innovation in digital manufacturing and increase U.S. competitiveness.

Basic Research

Underpinning all of our efforts and impacting all of the enduring Army challenges is a strong basic research program. Army Basic Research includes all scientific study and experimentation directed toward increasing fundamental knowledge and understanding in those fields of the physical, engineering, environmental, and life sciences related to long-term national security needs. The vision for Army Basic Research is to advance the frontiers of fundamental science and technology and drive long-term, game-changing capabilities for the Army through a multi-disciplinary portfolio teaming our in-house researchers with the global academic community to ensure overwhelming land-warfighting capabilities against any future adversary.

While we have made some significant adjustments within the Basic Research investments within the Army, we will continue to emphasize several areas that we feel have a high payoff potential for the Warfighter. These areas include: Materials in Extreme Environments; Quantum Information and Sensing; Intelligent Autonomous Systems; and Human Sciences/Cybernetics.

For centuries, the fabrication of solid materials has hinged largely on manipulating a narrow range of temperatures and pressures. Our Materials in Extreme Environments initiative invests in new revolutionary and targeted scientific opportunities to discover and exploit the fundamental interaction of matter under extreme static pressures and magnetic fields, controlled electromagnetic wave interactions (microwave, electrical) and acoustic waves

(ultrasound) to dramatically enhance fabrication and create engineered materials with tailored microstructures and revolutionary functionalities.

We are in the midst of a second quantum revolution – moving from merely computing quantum properties of systems to exploiting them. Areas of particular focus for the Army include quantum enhanced sensing and imaging, quantum communications, quantum algorithms, and quantum simulations. For example, an Army-specific quantum-enabled capability is an exact polynomial-time quantum-chemistry algorithm that directly impacts the design of propellants, explosives, medicines, and materials.

To enable the Warfighter, animal-like intelligence is desired for simple autonomous platforms, such as robotic followers, and for aerial and ground sensor platforms. We are investing in research that will enable highly intelligent systems that allow platforms to set waypoints autonomously, increasing mission effectiveness; followers that recognize the actions of their unit, that can perceive when the unit is deviating from a previously prescribed plan and know enough to query why; and that recognize when the unit is resting and be capable of doing so without explicit instructions from the Soldier.

Regardless of specific definition, human sciences are critical and can safely be predicted to become pervasive across all Army research activities. Cognitive predictions of social person-to-person communication based on observed gestures, eye movement, and body language are becoming possible. In addition, brain-to-brain interaction is emerging as a potential paradigm based on external sensors and brain stimulation. The Army will continue to study these and other possible techniques, to understand shared knowledge, social coordination, discourse comprehension, and detection and mitigation of conflict. Cognitive models combined with sensors also have the potential for dramatic breakthroughs in human-autonomy interaction, including aspects such as active learning algorithms, real-time crowd-sourcing with humans and machines in the cloud, and maximizing AI prediction accuracy. Devices and sensors that are wearable or implantable (including biomarkers and drug therapy) have the potential to enhance performance dramatically and to augment sensory information through new human-sensor-machine interface designs.

The role of Basic Research to provide the knowledge, technology, and advanced concepts to enable the best equipped, trained and protected Army to successfully execute the national security strategy, cannot be understated. The key to success in Basic Research is picking the right research challenges, the right people to do the work, and providing the right level of resources to maximize the likelihood of success.

Impact of Sequestration

I am often asked what impact sequestration had on the Army's S&T portfolio, so I would like to address some of the impacts we have seen. The FY13 application of sequestration targets (hitting every Program Element in the S&T portfolio by a set percentage) forced the Army into a scenario where we decremented programs that we would have protected, if given the opportunity. This lack of flexibility made for some very bad business and technical ramifications. Within the S&T community, we were able to balance our sequestration targets at the Program Element, vice Project level – giving us the ability to avoid civilian Reduction in Force (RIF) actions where possible. That said, sequestration did result in unfunded efforts and delays in applied research and technology development areas across the S&T portfolio. More generally, the sequestration cuts added unnecessary risk to acquisition programs and delayed the transition of critical capabilities to the Warfighter.

However, by far the most serious consequence of sequestration (and the related pay freezes, shutdowns, conference restrictions, etc.) has been the impact on our personnel. Without a world-class cadre of scientists and engineers, the Army S&T enterprise would be unable to support the needs of the Army. The Army Labs and Research, Development and Engineering Centers have reported multiple personnel leaving for other job opportunities or early retirement. For example, the Night Vision and Electronic Sensors Directorate lost eight personnel in the two months prior to the well-publicized DoD-wide furloughs, compared to an average annual loss of around 19 personnel. These losses include personnel across experience levels with specialized expertise critical to the Army. While the average attrition rate over the past two years is running at about 8% (similar to a typical attrition rate found in prior years), the concerning impact is that 60% of the personnel leaving the Army are NOT eligible for retirement. This is a big change. During our exit interviews, reasons cited included conference restrictions (impeding the ability to progress professionally) coupled with increasing job insecurity due to budget decrements and planned manpower reductions. Complicating this loss of technical expertise is the restriction on hiring replacements for the lost government civilians. We are on a replacement cycle that varies between 1 hire per every 3 losses at one lab, to 1 hire for every 20 losses at another. This pattern of loss is unsustainable if we hope to maintain a premier technical workforce. Finally, as we address the 2013 National Defense Authorization Act (NDAA), Section 955 language which mandates a reduction in the civilian workforce commensurate with a reduction in the military, we must confront the impacts of any civilian reductions, which are implemented through a personnel process that tends to primarily impact those

employees who have less tenure in the government. For the S&T community that typically impacts those areas of new technical emphasis within the DoD – key areas such as cyber research and systems biology.

While the Bipartisan Budget Act has provided some relief and stability for FY14 and FY15, the uncertainty again looming on the horizon makes it even more difficult to recruit and retain the scientists and engineers the Army depends on. As you know, the key to any success within the Army lies with our people.

The S&T Enterprise Infrastructure and Workforce

Our laboratory infrastructure is aging, with an average approximate age of 50 years. Despite this, the S&T Enterprise manages to maximize the scarce sustainment, restoration, and modernization funding and the authorities for minor military construction using NDAA, Sec. 219 funding to minimize the impact on the R&D functions with the Enterprise. However, we are only making improvements to our infrastructure at the margins, and where possible we have used MILCON, through your generous support and unspecified minor construction to modernize facilities and infrastructure. However, we do acknowledge that much of the Army is in a similar position. This is not a long-term solution. While the authorities that you have given us have been helpful, they alone are not enough, and we are still faced with the difficulty of competing within the Army for ever-scarcer military construction dollars at the levels needed to properly maintain world-class research facilities. This will be one of our major challenges in the years to come and I look forward to working with OSD and Congress to find a solution to this issue.

The S&T community affords us the flexibility and agility to respond to the many challenges that the Army will face. Without the world-class cadre of over 12,000 federal civilian scientists and engineers and the infrastructure that supports their work, the Army S&T Enterprise would be unable to support the needs of the Army. To maintain technological superiority now and in the future, the Army must maintain an agile workforce. Despite this current environment of unease within the government civilian workforce, exacerbated by conference restrictions, budget uncertainty, furloughs, and near zero pay increases, we continue to have an exceptional workforce. But, as I mentioned earlier, attracting and retaining the best science and engineering talent into the Army Laboratories and Centers is becoming more and more challenging. Our laboratory personnel demonstrations give us the flexibility to enhance recruiting and afford the opportunity to reshape our workforce, and I appreciate Congress' continued support for these authorities to include the flexibilities given to the Laboratories and Centers in the 2014 NDAA, Section 1107 language. With two exceptions (the Army Research

Institute (ARI) for the Behavioral and Social Sciences and the Space and Missile Defense Command Technical Center (SMDCTC)), all of our laboratories and centers are operating under this program (ARI and SMDCTC were never designated as Science and Technology Reinvention Laboratories). The flexibilities given to the laboratories and centers allow the laboratory directors the maximum management flexibility to shape their workforce and remain competitive with the private sector.

The Army S&T Enterprise cannot survive without developing the next generation of scientists and engineers. We continue to have an amazing group of young scientists and engineers that serve as role models for the next generation. For example, last year Dr. Ronald Polcawich, a researcher at the U.S. Army Research Laboratory (ARL), was named by President Obama to receive a 2012 Presidential Early Career Award for Scientists and Engineers as one of the nation's outstanding young scientists for his work in Piezoelectric-Micro Electro-Mechanical Systems (PiezoMEMS) Technology. Dr. Polcawich, is leading a team of researchers at the ARL in studying PiezoMEMS with a focus on developing solutions for RF systems and actuators for millimeter-scale robotics. These actuators combined/integrated with low power sensors are being developed to enable mm-scale mechanical insect-inspired robotic platforms.

The need for STEM literacy, the ability to understand and apply concepts from science, technology, engineering and mathematics in order to solve complex problems, goes well beyond the traditional STEM occupations of scientist, engineer or mathematician. The Army also has a growing need for highly qualified, STEM-literate technicians and skilled workers in advanced manufacturing, logistics, management and other technology-driven fields. Success and sustainment for the Army S&T Enterprise depends on a STEM-literate population to support innovation and the Army must contribute to building future generations of STEM-literate and agile talent.

Through the Army Educational Outreach Program (AEOP), the Army makes a unique and valuable contribution to meet the national STEM challenge - a challenge which includes the growing demand for STEM competencies; the global competitiveness for STEM talent; an unbalanced representation of our nation’s demographics in STEM fields; and the critical need for an agile and resilient STEM workforce. AEOP offers a cohesive, collaborative portfolio of STEM programs that provides students, as well as teachers, access to our world-class Army technical professionals and research centers. Exposure to STEM fields and STEM professionals is critical to growing the next generation of STEM-literate young men and women who will form the Army’s workforce of tomorrow.

In the 2012-2013 academic year, AEOP directly engaged more than 66,000 students and nearly 1,500 teachers in authentic research experiences. Almost 2,351 Army Scientists and Engineers (S&E's) provided mentorship, either from our in-house research laboratories or through our university partnerships. Additionally in FY13, we initiated a comprehensive evaluation strategy (the first of its kind) that uses the government and a consortium of STEM organizations known for their nationwide education and outreach efforts to annually assess our program. Aligned with Federal guidance, AEOP requires the evaluation of all elements of the program based on specific, cohesive, metrics and evidence-based approaches to achieve key objectives of Army outreach; increased program efficiency and coherence; the ability to share and leverage best practices; as well as focus on Army priorities. The AEOP Priorities are:

- STEM Literate Citizenry: Broaden, deepen and diversify the pool of STEM talent in support of the Army and our defense industry base.
- STEM Savvy Educators: Support and empower educators with unique Army research and technology resources.
- Sustainable Infrastructure: Develop and implement a cohesive, coordinated and sustainable STEM education outreach infrastructure across the Army.

For FY15, we are concentrating on implementing evidence-based program improvements, strengthening additional joint service sponsored efforts, and identifying ways to expand the reach and influence of successful existing programs by leveraging partnerships and resources with other agencies, industry and academia.

New Approaches to Enhance Innovation

It is widely acknowledged that innovation depends on bringing multiple scientific disciplines together to engage in collaborative projects -- often yielding unpredictable, yet highly productive results. Formal and informal interactions among scientists lead to knowledge-building and research breakthroughs. These types of collaborations are happening on a day-to-day basis across our labs and engineering centers to produce the superior technology that our Army needs today, tomorrow and beyond. With shrinking budgets and huge leaps in the pace of technological change, our Army science and technology organizations must do more with less and faster than ever before to develop technology that will ensure mission success for the Army's first battle after next. To this end, we must more succinctly leverage scientific discovery from our academic and industry base by

increasing the scientific engagement and flow of ideas that leads to ground breaking innovation.

In 1945, Vannevar Bush's concepts documented in "Science - the Endless Frontier" stressed the necessity of a robust/synergistic university, industry and government laboratory research system. Over the years, the rigid and insular nature of the defense laboratories have caused an erosion of that university/industry/government lab synergy that is critical to the discovery, innovation and transition of science and technology important to national security.

In an effort to reenergize that synergy, the US Army Research Laboratory (ARL) is working to extend their alliances through an Open Campus Concept that brings together under one roof the triad of industry, academia, and government. Leveraging the cutting-edge innovation of academia, the system development and transition expertise of industry and their own Army-focused fundamental research; ARL can harness the power of the triad to produce revolutionary science and technology more efficiently and effectively. The Open Campus Concept creates an ecosystem for academia, defense labs, and industry to share people, facilities and resources to develop and deliver transformative science oriented on solving complex Army problems. It will provide the means for our world-class scientific talent to work together in state-of-the-art facilities to provide innovation that allows rapid transition of technology to our Soldiers. ARL's Open Campus Concept could lead to a new business model that would transform the defense laboratory enterprise into an agile, efficient and effective laboratory system that supports the continuous flow of people and ideas to ensure transformative scientific discovery, innovation and transition critical to national security.

Finally, we are increasingly mindful of the globalization of S&T capabilities and expertise. Our International S&T strategy provides a framework to leverage cutting edge foreign science and technology enabled capabilities through Global Science and Technology Watch, engagement with allies and leadership initiatives. Global S&T Watch is a systematic process for identifying, assessing, and documenting relevant foreign research and technology developments. The Research, Development and Engineering Command's (RDECOM) International Technology Centers (ITCs), Engineer Research and Development Center (ERDC) international research office and the Medical Research Materiel Command's OCONUS laboratories identify and document relevant foreign S&T developments. We have initiated a new process to strategically identify and selectively engage our allies when their technologies and materiel developments can contribute to Army needs and facilitate coalition interoperability. The

resultant engagements will augment the existing bilateral leadership forums we currently maintain with the United Kingdom Canada, Germany and Israel which provide both visibility of and management decisions on allied developments that merit follow-up for possible collaboration.

Summary

As the Army S&T program continues to identify and harvest technologies suitable for transition to our force, we aim to remain ever vigilant of potential and emerging threats. We are implementing a strategic approach to modernization that includes an awareness of existing and potential gaps; an understanding of emerging threats; knowledge of state-of-the-art commercial, academic, and government research; as well as a clear understanding of competing needs for limited resources. Army S&T will sharpen its research efforts to focus upon those core capabilities it needs to sustain while identifying promising or disruptive technologies able to change the existing paradigms of understanding. Ultimately, the focus remains upon Soldiers; Army S&T consistently seeks new avenues to increase the Soldier's capability and ensure their technological superiority today, tomorrow, and decades from now. The Army S&T mission is not complete until the right technologies provide superior, yet affordable, overmatch capability for our Soldiers. I will leave you with a last thought from the Secretary of the Army, the Honorable John McHugh.

> *"Our Strategic Vision is based on a decisive technological superiority to any potential adversary."*[6]
>
> *— Honorable John W. McHugh, 21st Secretary of the Army*

This is an interesting, yet challenging, time to be in the Army. Despite this, we remain an Army that is looking towards the future while taking care of the Soldiers today. I hope that we can continue to count on your support as we move forward, and I would like to again thank the members of the Committee for all you do for our Soldiers. I would be happy to take any questions you have.

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[6] Terms of Reference, FY12 Army Science Board Summer Study, Secretary of the Army, John M. McHugh, October 28, 2011.

Biography

Department of the Army

Ms. Mary J. Miller
Deputy Assistant Secretary of the Army (Research and Technology)

Ms. Miller was selected for the Senior Executive Service in August of 2005. In February of 2013, she was designated as the Deputy Assistant Secretary of the Army for Research and Technology. Ms. Miller is responsible for the entirety of the Army's Research and Technology program, spanning 16 Laboratories and Research, Development and Engineering Centers, with more than 12,000 scientists and engineers and a yearly budget of just over $2 billion dedicated to empowering, unburdening and protecting Soldiers.

CAREER CHRONOLOGY:

- Feb 2013 – Present: Deputy Assistant Secretary of the Army (Research and Technology
- Sep 2012 – Feb 2013: Acting Deputy Assistant Secretary of the Army (Research and Technology
- Dec 2010 – Sep 2012: Deputy Program Executive Officer Soldier
- Aug 2005 – Dec 2010: Director for Technology, Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology, Pentagon, Washington, D.C.
- Apr 2001 - Aug 2005: Deputy Director of Technology for Aviation, Missiles, Soldier and Precision Strike under the Director for Technology, OASA(ALT), Pentagon, Washington, D.C.
- Oct 1992 - Apr 2001: Team Leader Nonlinear Optical Processes Team, U.S. Army Research Laboratory (ARL), Adelphi, MD
- Jun 1999 - Jun 2000: Science and Technology Liaison to the Deputy Chief of Staff for Operations – Force Development (now the DCS G8-FD). Pentagon, Washington, D.C.
- Mar 1990 – Oct 1992: Team Leader, Advanced Optics Team, Project Lead for the Visible/Near Infrared (VIS/NIR) Sensor Protection efforts, Night Vision & Electro-Optics Directorate, Laser Division, Ft. Belvoir, VA
- Jul 1984 – Mar 1990: Electronics Engineer, Night Vision & Electro-Optics Directorate, Laser Division, Ft. Belvoir, VA

College:
- Masters of Business Administration from the University of Tennessee, Knoxville, TN.
- Masters of Science in Electrical Engineering, Electro-Physics from the George Washington University, Washington, D.C.
- Bachelor of Science in Electrical Engineering from the University of Washington, Seattle, WA.

Awards and Honors:
- Army Research & Development Achievement Award in 1988 for her technical achievement in the "Development of Nonlinear Materials for Sensor Protection."
- Four patents awarded for sensor protection designs, two additional patents pending.

Certifications:
- Certified Level III in Program Management
- Certified Level III SPRDE, Systems Engineering
- Certified Level II SPRDE, Program Systems Engineering

Professional memberships and associations:
- Association of the United States Army (AUSA), member since 2003

Major Publications:
Ms. Miller has published more than 50 papers and has addressed over 30 major commands and international groups with technical presentations. She served as a conference committee member and co-chair for SPIE Conference on Nonlinear Optical Liquids, 1996-1998 and served as a peer-reviewer for technical papers in her area of specialty submitted to the Journal of Applied Optics, Applied Optics and Optics Letters from 1987-1999.

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March 2013

NOT FOR PUBLICATION UNTIL RELEASED BY THE
HOUSE ARMED SERVICES COMMITTEE
INTELLIGENCE, EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

STATEMENT OF
REAR ADMIRAL MATTHEW L. KLUNDER, UNITED STATES NAVY
CHIEF OF NAVAL RESEARCH

BEFORE THE
INTELLIGENCE, EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE
OF THE
HOUSE ARMED SERVICES COMMITTEE
ON
THE FISCAL YEAR 2015 BUDGET REQUEST

MARCH 26, 2014

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INTELLIGENCE, EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

Introduction

It is an honor to report on Department of the Navy (DoN) Science and Technology (S&T) and discuss how the President's FY 2015 Budget supports the Navy and Marine Corps (USMC). The FY 2015 Budget requests approximately $2 billion for Naval S&T. The Navy and Marine Corps use S&T to enable the Fleet/Force to maintain the technological edge necessary to prevail in any environment where we may be called to defend U.S. interests. We work with the Secretary of the Navy (SECNAV), Chief of Naval Operations (CNO) and Commandant of the Marine Corps (CMC) to balance the allocation of resources between near-term technology development and long-term research. We strive to improve affordability, communication with the acquisition community, and engage with stakeholders.

Science and Technology Strategic Plan

The Naval S&T Strategic Plan guides our investments and is regularly updated by Navy and USMC leadership to validate alignment of S&T with current missions, leadership priorities, and future requirements. It ensures S&T has long-term focus, meets near-term objectives, and makes what we do clear to decision makers, partners, customers and performers. The Plan identifies nine areas that help to focus S&T to meet Navy/USMC needs: 1) Assure Access to Maritime Battlespace, 2) Autonomy and Unmanned Systems, 3) Expeditionary and Irregular Warfare, 4) Information Dominance, 5) Platform Design and Survivability, 6) Power and Energy, 7) Power Projection and Integrated Defense, 8) Total Ownership Cost, and 9) Warfighter Performance. Our goal is to move from existing systems and concepts of operations toward a warfighting capability to counter predicted threats in an increasingly complex and uncertain environment. Beginning with the evolution of current systems through incremental improvement and spiral development of known technology, we move toward exploiting yet-to-be-discovered, disruptive, game-changing technologies. The S&T Strategic Plan and focus areas are currently under review and will be updated in the near future.

Implementing the Strategy

Based on time-to-delivery and specification of need, Naval S&T can be viewed as fitting into four primary areas – Discovery and Invention (D&I), Leap Ahead Innovations (Innovative Naval Prototypes/INP), Acquisition Enablers (Future Naval Capabilities/FNC), and a Quick Reaction capability to respond to emerging requirements. Our S&T portfolio balances a range of complementary but competing initiatives by supporting advances in established operational areas – while sustaining long-term research that may prove disruptive to traditional operational concepts.

Discovery and Invention

Discovery and Invention (D&I) includes basic research (6.1) and early applied research (6.2) in areas essential to Naval missions, as well as emerging areas with promise for future application. D&I develops fundamental knowledge, provides a basis for future Navy/Marine Corps systems, and sustains our Scientist/Engineer workforce. D&I develops knowledge from which INP, FNC, and Quick Reaction efforts are generated and is the foundation for advanced technology.

Approximately 45 percent of ONR investments are in D&I, with roughly 60 percent of that total executed by academic and non-profit performers. D&I is peer reviewed by outside experts who independently assess scientific merit – and overseen by ONR program officers and senior leadership. Investment decisions are guided by risk, impact, significance, originality, principal investigator, and budget resources.

ONR's University Research Initiative (URI) includes the Multidisciplinary University Research Initiative (MURI), the Defense University Research Implementation Program (DURIP), and the Presidential Early Career Award for Scientist and Engineers (PECASE). MURI supports teams of researchers investigating topics that intersect multiple technical disciplines. DURIP provides grants for the purchase of instrumentation necessary to perform research essential to the Navy. PECASE recognizes achievements of young scientists/engineers and encourages them to explore professions in academia and Naval laboratories. The Basic Research Challenge funds promising research not addressed by ONR's core program. The Young Investigator Program supports scientists and engineers with exceptional promise for Naval research. Research opportunities for undergraduate and grad students, fellows, and future faculty members are provided by the Naval Research Enterprise Internship Program (NREIP), where participants work at Naval laboratories and warfare centers. The In-House Laboratory Independent Research (ILIR) and Independent Applied Research (IAR) programs sponsor critical research, while furthering the education of scientists and engineers at warfare centers. ONR also brings Historically Black Colleges and Universities and Minority Institutions (HBCU/MI) together with Naval laboratories and warfare centers to give students hands-on experience in the Naval research environment.

Supporting warfighters depends on our Science, Technology, Engineering and Mathematics (STEM) workforce – but that workforce is aging. With half of Navy science and engineering professionals retirement eligible by 2020, we face an acute shortfall in our Naval engineering, computer science and ocean engineering workforce. Production of engineers has been flat for two decades, and less in specialty fields. A complicating factor is that DoN must rely on U.S. citizens for classified work; the number of U.S. citizen STEM graduates will not keep up with domestic or international competition for the same talent. ONR evaluates STEM investments with metrics tailored to measure numbers of students and teachers, overall impact, and overall ability to achieve Naval requirements in coordination with other federal STEM programs.

Leap Ahead Innovations (Innovative Naval Prototypes)

Innovative Naval Prototypes (INP) total about 12 percent of the S&T budget. INPs are high-risk/high-payoff opportunities from D&I that are discontinuous, disruptive departures from established requirements and operational concepts that can dramatically change the way Naval forces fight, while reducing acquisition risk. Overseen by the Naval Research, Development, Testing and Evaluation (RTD&E) Corporate Board (Undersecretary of the Navy; Assistant Secretary of the Navy for Research, Development and Acquisition (ASN-RDA); Vice CNO; Assistant CMC; Director of Innovation, Test, and Evaluation and Technology Requirements; Deputy Assistant Secretary of the Navy for RDT&E; and Deputy Under Secretary of the Navy for Plans, Policy, Oversight and Integration), the goal is to prove concepts and mature technology in 4-7 years, allowing informed decisions about risk reduction and transition to acquisition programs. INP Program Managers and Deputies are from ONR and the acquisition community.

INPs include:

Integrated Topside (InTop) will enable the Navy to operate freely in the electromagnetic spectrum while denying adversaries' ability to do the same through development of multi-beam, multi-function ultra-wideband apertures and Radio Frequency (RF) equipment for all ship classes. We are developing Electronic Warfare, Information Operations, Radar, Satellite, and Line of Sight Communications using: 1) open architecture RF hardware/software to enable a broad industrial base to contribute to development of affordable systems, and 2) modular systems to enable technology to be scalable across Navy platforms and reduce logistics, training, and maintenance costs. We continue prototype tests/demonstrations with testing by the Naval Undersea Warfare Center (NUWC) for submarine Satellite Communications (SATCOM) and by the Naval Research Laboratory (NRL) for the Surface Electronic Warfare Improvement Program (SEWIP). Accomplishments include over the air testing of the Submarine Wideband SATCOM Antenna transmitter, integration of all antennas and electronics for the Electronic Warfare/Information Operations/Line of Sight Communications Advanced Development Model, building the Low Level Resource Allocation Manager, and award of the Flexible Distributed Array Radar contract.

The Large Displacement Unmanned Undersea Vehicle (LDUUV) program is developing a reliable, fully autonomous, long endurance UUV capable of extended operation (60+ days) in cluttered littoral environments. The program has already built three vehicles and is developing the energy, autonomy and core systems to operate in a complex ocean environment near harbors, shorelines, and other high traffic locations. Key goals include doubling current air-independent UUV energy density, using open architecture to lower cost, and enabling full pier to pier autonomy in over-the-horizon operations. Achieving these goals will reduce platform vulnerability, enhance warfighter capability and safety, and close gaps in critical and complex mission areas by extending the reach of the Navy into denied areas.

The Autonomous Aerial Cargo/Utility System (AACUS) is developing intelligent, autonomous capabilities for rapid, affordable, reliable rotorcraft supply in permissive, hostile and GPS-denied settings. AACUS-enabled aircraft will be supervised by field personnel from a handheld device. Challenges include dynamic mission management and contingency planning, as well as landing execution and obstacle avoidance. AACUS has already demonstrated numerous successful flights and is designed for open system architecture to promote modularity and affordability. It could be used in logistics missions, Casualty Evacuation (CASEVAC), combat rescue, and humanitarian aid missions. S&T partners include the Air Force, Army, USMC, National Aeronautics and Space Administration (NASA), Naval Air Systems Command (NAVAIR), and other academic, private sector, and government organizations.

The Electromagnetic Railgun (EMRG) has multi-mission potential for long-range land-attack, ballistic and cruise missile defense, and anti-surface warfare against ships and small boats. Fired by electric pulse, Railgun eliminates gun propellant from magazines resulting in greater resistance to battle damage. Since 2005, launch energy has advanced by a factor of 5 (to 32 mega joules) with potential to launch projectiles 110 nautical miles. Projectile design is underway, with early prototype testing, component development, and modeling and simulation.

Barrel life has increased from tens of shots to over 400, with a program path to achieve 1000 shots. Advanced composite launchers have been strength tested to operational levels. Physical size of the pulsed power system was reduced by a factor of 2.5 through increased energy density so the system will fit in current and future surface combatants. Current research is focused on a rep-rate capability of multiple rounds per minute which entails development of a tactical prototype gun barrel and pulsed power systems incorporating advanced cooling techniques. Components are designed to transition directly into prototype systems now being conceptualized. ONR is working with Naval Sea Systems Command (NAVSEA) and the Office of the Secretary of Defense (OSD) Strategic Capabilities Office to ensure commonality and reduce the need for expensive redesign. Developmental tests are ongoing at Naval Surface Warfare Center, Dahlgren and NRL, along with evaluations of integration into new and existing Naval platforms.

Electromagnetic Railgun testing aboard a Joint High Speed Vessel (JHSV) will begin in 2016 and utilize components largely in common with those developed and demonstrated at Dahlgren. At-sea testing is one of the critical events planned in coming years to demonstrate multi-mission capability. At-sea tests capture lessons learned for incorporation into a full future tactical design and allow us to understand any potential modifications before fully integrating the technology on our ships. Further, it will gather data to support design for reliability and sustainability related to Railgun operation in a marine environment.

Finally, although similarly high-risk and disruptive, SwampWorks programs are smaller than INPs and intended to produce quick results in 1-3 years. SwampWorks efforts have substantial flexibility in planning and execution, with a streamlined approval process. Formal transition agreements are not required, but SwampWorks programs have advocates outside ONR, either from the acquisition community or Fleet/Force. SwampWorks products are frequently inserted into Fleet/Force experimentation.

Directed Energy Roadmap

Development and ship integration of energy-intensive systems such as Directed Energy Weapons (DEW) (e.g. high-energy lasers (HEL) and High Powered Radio Frequency (HPRF)) and EMRG requires careful engineering. Shipboard integration considerations include space, weight, power, cooling, stability, impact on combat systems, fire control, and interfaces. Technical maturity and integration will be accomplished through a measured approach to allocation of ship services and interface with ship systems.

Navy's near-term focus is on a Solid State Laser Quick Reaction Capability (SSL-QRC), which will field a prototype system based on the Laser Weapon System (LaWS), and the Solid State Laser Technology Maturation (SSL-TM) program. The Navy plans to deploy SSL-QRC (LaWS) to the Persian Gulf aboard USS PONCE in 2014 to demonstrate the ability to meet gaps in ship self-defense against armed fast boats and unmanned aerial vehicle threats. Navy is also investigating the use of non-lethal HPRF technologies for vessel stopping and counter UAS. Development continues on Free Electron Laser technologies for long-term solutions requiring power levels beyond that which Solid State Lasers can deliver.

SSL-TM will help determine the load capacity and most effective means to integrate a HEL on surface ships such as DDG-51 and the Littoral Combat Ship. The SSL-TM goal is to demonstrate a 100-150 kilowatt Advanced Development Model (ADM) by 2016. The program will address technical challenges in rugged laser subsystems, optics suitable for maritime environments, and capability to propagate lethal power levels in the maritime atmosphere. The SSL-TM prototype will be sufficiently mature to commence an acquisition program of record.

Progress on technologies covered in the Naval DE Roadmap efforts (HEL, HPRF) and EMRG are projected to result in capabilities that meet future requirements. As part of the Navy's Two-Pass Six-Gate review process for major acquisition programs, a Gate 6 Configuration Steering Board (CSB) is conducted annually for each ship class. Once a DEW achieves maturity, the CSB reviews technology, requirements, and cost to determine if transitioning to acquisition program and incorporation in a ship class is warranted. If warranted, the CSB determines on which hull the technology will be incorporated. For technology that provides significant capability but also significant installation impact to a ship, cost/benefit will be weighed against installation during new construction. If the installation impact is less, the technology could be included as part of a back fit or post-delivery installation.

In 2013, NAVSEA developed the Naval Power Systems Technology Development Roadmap (NPS TDR). NPS TDR aligns power system developments with warfighter needs, including DEWs and energy-intensive weapons and sensors for shipboard use, to ensure that future ships are capable of accepting power and cooling loads of such systems as they are developed. The roadmap addresses new construction integration and back fit of technologies for ships in service. NPS TDR is adapted to evolving requirements from weapons and sensor system developments, as well as changes in the Navy's 30-year shipbuilding plan, and will be updated every two years. NPS TDR introduced the concept of an Energy Magazine to provide the required power from the ship's electrical system and interface with high powered weapons and sensors. The Energy Magazine will initially support near-term applications, such as HEL, on a legacy platform. As new systems become available, the Energy Magazine can be expanded to accommodate multiple loads by providing the appropriate power conversion and energy storage.

The Naval Directed Energy Steering Group is currently drafting a Naval DE roadmap based on the Naval DE Vision and Strategy to establish goals, principles, priorities, roles, responsibilities, and objectives regarding acquisition and fielding of DEWs by the Navy and Marine Corps. This roadmap will address the way ahead for platform requirements, as well as power and cooling necessary to support these systems.

Acquisition Enablers (Future Naval Capabilities)

Acquisition Enablers (AE) are the critical component of our transition strategy. AE consists of our Future Naval Capabilities (FNC) program, USMC Advanced Technology Development (6.3) funds, Joint Non-Lethal Weapons Directorate (6.3) funds, the Manufacturing Technology (ManTech) program, and Low Observable, Counter Low Observable funds.

FNCs are near-term (2-4 year), requirements-driven, delivery-oriented S&T projects. FNCs deliver mature technologies to acquisition sponsors for incorporation into systems that provide

new capabilities. FNCs use a collaborative process involving requirements, research, acquisition, and Fleet/Force communities to align this part of the S&T portfolio with Naval Capability Gaps identified by the Office of the Chief of Naval Operations (OPNAV) and the Marine Corps Combat Development Command (MCCDC). A gap is any capability required to achieve Naval objectives that is not achievable with current platforms, weapon systems, doctrine, organizational structure, training, materials, leadership, personnel or facilities and requires S&T investment to solve or overcome. Capability Gaps define the requirement, not how to meet it.

FNCs are aligned to functional areas called "Pillars": Sea Shield, Sea Strike, Sea Basing, FORCEnet, Naval Expeditionary Maneuver Warfare, Capable Manpower, Force Health Protection, Enterprise and Platform Enablers, and Power and Energy. FNC projects address specific gaps in each of those areas, with final prioritization approved by a 3-Star Technology Oversight Group (TOG) representing OPNAV, Marine Corps, U.S. Fleet Forces Command, ASN-RDA, and ONR. FNCs are based on D&I investments where technology can be matured from Technology Readiness Level (TRL) 3 to TRL 6 in 3-5 years. Selection takes account of related work in the Department of Defense (DoD), government agencies, industry and Naval centers of excellence. Our investments focus on the most pressing gaps, with funding changes based on successful transitions, reprioritization, new starts, and evolving Naval needs. As FNC products mature, Technology Readiness Levels (TRL) change, moving products from 6.2 to 6.3 PEs. Year one is mostly 6.2; the final year mostly 6.3 – with a mix of 6.2/6.3 between. As FNC products transition from S&T to Advanced Component Development and Prototypes (6.4) and Engineering and Manufacturing Development (6.5), responsibility for continued development shifts from ONR to acquisition commands.

Approved FNC products have Technology Transition Agreements to document the commitment of the resource sponsor, acquisition program, and ONR to develop, deliver and integrate products into new or upgraded systems. Every product is measured by technical and financial milestones. All products must meet required transition commitment levels for S&T development to continue. Products that no longer have viable transition paths are terminated with residual funding used to solve problems with existing projects, or start new projects in compliance with Navy priorities, charters, business rules and development guidelines. The measure of success is whether projects meet technology requirements and exit criteria, and whether acquisition sponsors have transition funds in programs to accept and integrate FNC products. The transition status of FNC products is actively monitored on an annual basis, with products terminated if the S&T is failing or the transition plan is no longer viable. Through the end of FY 2013, 216 FNC products completed S&T development (a success rate of 84%), with 41 FNC products terminated before completion.

Results are evaluated by a Transition Review Board (TRB) consisting of Naval Reserve Officers representing Requirements, Acquisition and S&T communities. The TRB provides an objective, independent assessment of FNC products after successful transition or termination, analyzing the causes and residual value of unsuccessful transitions and deployments. Even in case of products which do not deploy, there is significant residual value in technology that can be leveraged for follow-on S&T efforts and made available for future transitions. Nothing goes to waste.

Quick Reaction S&T

ONR maintains quick-reaction capability for projects lasting 12-24 months that respond to immediate requirements identified by Fleet/Force or Naval leadership. TechSolutions provides short-term solutions to immediate operational and tactical requirements. Accessible via Internet and SIPRnet, TechSolutions accepts recommendations from Sailors and Marines about ways to improve mission effectiveness through the application of technology. TechSolutions uses rapid prototyping to meet specific requirements, with each project structured around definable metrics, and appropriate acquisition/test systems by integrated product teams. While neither a substitute for the acquisition process, nor a replacement for systems commands, TechSolutions prototypes deliver solutions to address immediate needs that can be easily transitioned to the Fleet/Force.

Technology development often occurs faster than DoD Planning, Programming, Budgeting and Execution (PPBE) can respond. Our Technology Insertion for Program Savings (TIPS) program provides current-year funding (inside the PPBE process), eliminating time lag in the PPBE cycle. TIPS provides up to $2 million for development efforts taking no more than two years, coupled with Fleet/Force support and resource sponsor commitment to fund moving the technology into the acquisition Program of Record (POR) or operating system. TIPS focuses on improvements that substantially reduce operating and support costs for warfighting systems.

In partnership with ONR, Naval Warfare Development Command (NWDC), Naval Postgraduate School, Naval War College and Marine Corps Warfighting Lab (MCWL) assess new warfighting concepts and technologies. Initiatives in support of our maritime strategy are applied, tested, analyzed and refined through war games, exercises, experiments and operational lessons learned.

Government Accountability Office (GAO) Report on Technology Transition

In the March 2013 Government Accountability Office Report, "DEFENSE TECHNOLOGY DEVELOPMENT: Technology Transition Programs Support Military Users, but Opportunities Exist to Improve Measurement of Outcomes (GAO-13-286)," GAO reported:

"…the Office of Naval Research (ONR) has a well-established technology transition focus. ONR's Office of Transition manages the Future Naval Capabilities (FNC) portfolio, which is the Navy's largest transition program—for which nearly $450 million was budgeted in fiscal year 2013. The program, which was initiated in 1999, seeks to provide the best technology solutions to address operational requirements, delivering technology products to acquisition programs that enhance capabilities within a 5-year time frame. ONR's Offices of Transition and Innovation also support rapid technology transition to the fleet, force, and acquisition communities via the Rapid Technology Transition (RTT), Technology Insertion Program for Savings (TIPS), TechSolutions (TS), and SwampWorks and Experimentation (SW/Exp) programs." (p. 9)

GAO said, "The Navy uses a Transition Review Board to monitor completed projects from the Future Naval Capabilities, Rapid Technology Transition, and Technology Insertion Program for Savings programs. The board determines and reports on whether transitioned projects are utilized in systems that support Navy warfighters. The Navy determined, for example, that of the 155 technology products the Future Naval Capabilities program delivered to acquisition

programs between fiscal years 2006-2011, 21 percent were subsequently deployed to fleet forces, 35 percent were still with the acquisition programs, and 44 percent failed to deploy. For projects that do not successfully deploy, the board assesses whether there are other benefits achieved, such as technologies leveraged for follow-on S&T work. The board also identifies obstacles to transition, such as loss of interest by the user or inadequacy of funding. These findings, along with a detailed one-page summary for each project, are then used to inform the Navy's annual review process. We found that by maintaining this level of tracking, the Navy is better aware of the benefits and obstacles associated with a substantial portion of their S&T portfolio, which may better inform decisions made by Navy leadership." (pp. 21-22)

GAO continued, "At the program level, many program officials indicated that senior leadership engagement, particularly in providing oversight for projects through to transition, is essential to having an effective program. We found the Future Naval Capabilities program provides a good example of senior leadership positively affecting project management activities. Specifically, due to funding constraints in its fiscal year 2013 S&T budget, Navy senior leadership supported the termination of ongoing Future Naval Capabilities projects that were determined to be lower priorities so that new, higher priority projects could be pursued. Navy officials stated that this type of awareness and understanding at senior levels enables the Future Naval Capabilities program to make efficient decisions that are less likely to meet resistance and that support the highest priority projects being developed for transition opportunities. (p. 25)

"Several transition programs also emphasized the relationship between "working-level" stakeholders—S&T developers and acquisition programs or warfighters in the field—when discussing the keys to technology transition. These stakeholders manage expectations throughout a project and ensure it will meet user needs. This reduces the risk of completed projects languishing because funding is not available or because user requirements have changed, or both. Some programs that we reviewed use integrated product teams, which may be composed of individuals representing the requirements, acquisition, operational, and S&T communities, among others, to facilitate continuous communication with stakeholders and ensure that transition planning is on track. In the case of the Navy, integrated product teams identify capability gaps, provide input on which S&T projects may address those gaps, assess project progress, make sure transition strategies remain valid, and confirm funding is aligned to support transition. According to Navy officials, the results of integrated product team efforts also support information sharing across senior- and working-level stakeholders to validate development status and transition planning activities." (pp. 25-26)

GAO concluded, "We found the Future Naval Capabilities program uses technology transition agreements as management tools to increase the level of documented commitment as a project progresses over time. To accomplish this, the program has three levels for agreements that reflect the requisite knowledge available at different phases of a project. Key elements of an initial agreement include a basic project description, identification of initial exit criteria, a high-level integration strategy, and a likely transition funding source. As a project progresses, the other two levels of agreement require increasing commitment and specificity of requirements from stakeholders to develop, deliver, and integrate a Future Naval Capabilities project into an acquisition program or other form of deployment. Key elements of the second and third tier agreements involve refining and finalizing project descriptions, detailing exit criteria, providing

greater specificity about the integration strategy, and providing estimates for transition costs and eventually executing transition funding. Stakeholders review the agreements annually to revalidate the commitments laid out within the document. (p.27)

"We also found Transition Commitment Level (TCL) assessment tools… offer another means of validating that transition programs are investing in projects that have a firm transition commitment from prospective users. These tools provide scorecards that chart how well-defined the fundamental characteristics that support a strong commitment to transition projects are at a given point in time. The Future Naval Capabilities program uses a single TCL tool that documents level of transition commitment from project start to completion." (p.27)

S&T Highlights

The Naval S&T portfolio includes a range of projects and programs entering or about to enter the Fleet/Force. Examples follow.

Expeditionary Maneuver Warfare and Combating Terrorism

Marine expeditionary forces are forward-deployed and forward-based, right-sized to respond to missions across the range of military operations from combat to Humanitarian Assistance and Disaster Relief (HADR). This is best achieved by a Middleweight Force which can launch from the sea and project power in sophisticated anti-access, area-denial (A2/AD) environments. The imperative to lighten the load for every Marine and the Marine Air-Ground Task Force (MAGTAF) is critical, requiring research in technologies that increase speed, agility and range, develop advanced materials for lighter body armor, helmets and eye protection, while reducing fuel consumption and vulnerability to Improvised Explosive Devices (IEDs) and mines. We develop over-horizon, beyond line-of-sight, restricted environment communications, and adaptable sensor systems to detect, classify, identify, locate and track low level entities in urban clutter, improve situational awareness, and enhance real time tactical decision making.

Improving resilience of Marines enables them to more effectively, efficiently observe, orient, decide and act (OODA) in complex, stressful conditions. We explore technologies to provide autonomous logistics, and enhance fuel, water and maintenance self-sufficiency. On-demand, reduced logistics enable a high operational tempo, and allow the Corps to out-maneuver and dominate any enemy. Marines out-perform and out-think enemies by understanding battlespace in greater detail, making decisions with greater understanding of enemy intent, and getting inside the enemy decision cycle. To achieve this, ONR created a small unit leader training framework based on codified learning models and theories to deliver technology and knowledge products for the USMC Training and Education Command (TECOM) that maximizes learning and skill acquisition at minimal cost. We invest in S&T to improve training efficiency based on cutting-edge, neuro-cognitive, psychologically-driven instructional strategies that enable Sailors and Marines to survive the brutal environment of combat, as well as retain emotional and mental health after they leave the traumatic environment.

Current S&T investments include projects to improve On-Board Vehicle Power, Advanced Remanufacturing and Sustainment Technologies, and Internally Transportable Vehicle

Autonomy Conversion. Force Protection projects include development of Personal Protection Technologies, On-The-Move Detection-of-Threat Optics, the Modular Explosive Hazard Defeat System (MEHDS), and Ground Based Air Defense (On-the-Move). Fires projects (Advanced Ammunition and Energetics) include an Integrated Day-Night Sight, the High Reliability DPICM (Dual Purpose Improved Conventional Munition) Replacement Program, and High Performance Alloys for Weapons. Logistics applications will improve Pallet Handling and Packaging, a JP-8 Solid Oxide Fuel Cell, and Autonomous Resupply technology. Human Performance, Training and Education investments will provide an Advanced Training System for Small Unit Decision-Making, and Training to Optimize Use of Resilience Skills (TOURS). Finally, Intelligence, Surveillance and Reconnaissance projects include Night Wide Area Augmentation System (WAAS), Entity Disambiguation, and Semantic Web enablement to enhance mission-centric knowledge generation and delivery. Our S&T efforts are undertaken hand-in-glove with the Marine Corps Warfighting Laboratory at Quantico, Virginia, whose mission is to rigorously explore and assess Marine Corps concepts using an integral combination of war-gaming, concept-based experimentation, technology assessments, and analysis to validate, modify or reject the concept's viability, and identify opportunities for future force development.

Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR)

The proliferation of anti-access, area-denial (A2/AD) capabilities among potential adversaries drives the need for technologies that assure access for Naval forces. Our challenges include the requirement to project power despite A2/AD challenges and to provide information dominance to the warfighter.

Improved decision making is central to the Navy's S&T plan to provide information dominance to the warfighter. One goal is to develop a highly flexible, open architecture, information and decision making capability with applications enabling operational and tactical forces to function with the same distributed information base across all warfare and mission areas. Information gathering and analysis will be largely automated and autonomously controlled so warfighters can have more time to make decisions and execute plans. A key aspect of this is our use of the electromagnetic spectrum for dominance, while denying the same to our adversaries. To this end ONR, Navy, and the other services are working to deliver hardware and software to support electromagnetic spectrum dominance in the near and far term. Capabilities are in various stages of maturity and deployment.

ONR developed software to evaluate effectiveness of new Electronic Warfare countermeasures. When the Fleet identified a requirement to improve threat awareness and assess vulnerability to anti-ship cruise missiles using organic Electronics Support Measures (ESM) sensors and radar, ONR used the same software to address the new requirement by developing a Human-Machine Interface (HMI), installing it on ships, and deploying scientists to make the new HMI sailor friendly. This gave the Task Force a clearer picture of ESM effectiveness and vulnerabilities relative to current sensors, weather, and threats – allowing them to reassign sensor coverage and move platforms to reduce vulnerabilities.

The Joint Counter Radio Controlled Improvised Explosive Device Electronic Warfare (JCREW) effort is developing flexible, dynamic system architecture to detect IED signals across the entire spectrum and provide automated responses. Unlike current technology, JCREW is designed to allow detection and communication systems to operate simultaneously.

Ocean Battlespace Sensing

To continue to dominate in the maritime environment Naval forces must be able to accurately predict and adapt to ocean, air, littoral and riverine environments on both tactical and strategic levels. Recent changes in climate conditions and extremes have created an emerging need for more accurate and longer range forecasts for DoD and Naval operations. In support of the Navy's Task Force Climate Change, the National Oceanographic Partnership Program, and in partnership with the Air Force, Department of Energy, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and National Science Foundation (NSF), we invest in S&T to provide mobile autonomous environment sensing, match predictive capability to tactical requirements, develop systems that adapt to environmental variability, and integrate atmospheric and ocean models to enable better forecasting. Additional investments will provide a better understanding of surface wind impact on upper ocean dynamics and energy fluxes across ocean boundary layers, increase knowledge of high latitude Arctic environments, and enhance our ability to forecast operational conditions with longer lead times. The payoff is safer, more efficient Naval operations in maritime environments through improved immediate, seasonal and longer range forecasts.

ONR's environmental research is heavily field-oriented, employing oceanographic ships, aircraft, and autonomous air and undersea vehicles. For example, the Navy owns six University-National Oceanographic Laboratory System (UNOLS) Ocean Class Research Vessels that ONR schedules and supports in partnership with NSF. Construction of two replacement vessels is underway, with Auxiliary General Oceanographic Research Ship (AGOR) 27 – Research Vessel (R/V) *Neil Armstrong* assigned to Woods Hole Oceanographic Institution, and AGOR 28 – R/V *Sally Ride* assigned to Scripps Institution of Oceanography. Both are expected to begin research operations in FY 2015.

In addition, we are developing rapid, standoff mine countermeasures to support unencumbered maneuver of combatants, assure access, ensure strategic mobility and sustainment, decrease mine countermeasure (MCM) hazards, and increase the standoff range of combatants from minefields. ONR experiments with sensing and autonomy technologies help small vessels to operate at night, in all weather, at higher speeds, and with less risk over large, poorly mapped riverine systems. Our Advanced Undersea Weapon System (AUWS) will deliver targeting sensors and remotely controllable or autonomous weapons into chokepoints or channels to neutralize maritime threats. ONR's Advanced Sonar Technology for High Clearance Rate MCM in the surf and autonomous minehunting payloads for Unmanned Surface Vehicles (USV), reduce timelines for detecting, identifying and clearing floating, drifting, moored and bottom mines in shallow water.

ONR supports research in acoustic propagation and scattering to improve anti-submarine wide area surveillance, detection, localization, tracking, and attack capabilities against adversary submarines in noisy, cluttered shallow water environments. We provide S&T to mitigate effects

of acoustic systems on marine mammals, to improve probability of kill for undersea weapons, and to enable new undersea weapon concepts of operation. Projects include the Remote Aerial Sonar and Communications Laser (RASCL), Affordable Compact Bow Sonar for large deck surface ships, holding threat submarines at risk in forward areas, screening transiting battle groups, and providing torpedo defense for ships.

Sea Warfare and Weapons

ONR's major focus in this area is to improve surface, submarine, ground, and air platforms, as well as undersea weapon performance. S&T investments provide options for advanced electrical systems and components, and for survivable, agile, mobile, sustainable, manned and unmanned, surface and sub-surface sea platforms, and undersea weapons. Significant investments provide S&T to improve performance and affordability of the nation's strategic submarine assets under the Ohio Replacement Program (ORP), as well as Virginia-class submarines. Our Electric Ship Research and Development Consortium enlists academic institutions to develop electric power architectures and technologies to enable use of next generation high power sensors and weapons, including directed energy weapons (DEW) systems described earlier. Investments encompass projects to transition S&T necessary to improve performance and capabilities of our current fleet of torpedoes, undersea weapons and vehicles, as well as effective countermeasures and defensive weapons to protect against undersea weapon threats. Undersea vehicle S&T includes research, development and deployment of long-endurance, air-independent power systems for unmanned undersea vehicles (UUVs). Additionally, we utilize extensive experience in surface craft design and autonomy to provide the Fleet with unmanned surface vessels (USVs) capable of operating effectively in a range of marine environments.

A key enabler of these Sea Warfare and other capabilities is S&T investment in naval materials. These investments focus on performance and affordability of advanced materials for applications such as lightweight structures, corrosion and biofouling mitigation, maintenance cost-reduction, undersea acoustics, and energy- and power-dense electrical energy conversion and storage. These efforts explore and apply fundamental materials physics to discover and engineer future materials meeting warfighting platform demands now and in the future. Consistent with this approach, our investment in Integrated Computational Materials Engineering is a key contributor to the recently established Lightweight and Modern Metals Manufacturing Initiative (LM3I).

Warfighter Performance

Warfighter Performance S&T addresses the full range of research issues involving human system interactions, medical and biological systems, and supports the SECNAV mission of protecting the safety and privacy rights of human research subjects.

Human system research helps the DoN recruit the right people, assign them to the right jobs, while ensuring they have the right skills in safe systems that are designed to support effective decision making and collaboration. Our S&T investments in this area helps improve small team, platform, task force, and battle group operations by developing training technology and decision support systems that accommodate human capabilities and limits. ONR initiatives include simulation-based approaches to fleet integrated, multi-platform, multi-mission training and

experimentation that enable near-real time collaboration, decision-making and planning across platforms and organizations.

Warfighter performance goals are to enhance performance, improve the timeliness and quality of decision making, develop strategies to mitigate workload, resolve ambiguity, and reduce workload and manning, while improving situational awareness and speed of command. Training technology S&T designs virtual networked learning environments that exploit live assets, virtual simulators and artificially intelligent constructive (Live, Virtual, Constructive/LVC) entities in distributed training environments to increase individual and team skill, knowledge, expertise and experience in warfighting tasks. S&T enables the Navy and Marine Corps to effectively and affordably train in classrooms, simulated environments, and on deployment.

Medical S&T improves the health, well-being, protection and survival of personnel in undersea, shipboard and expeditionary settings. ONR develops medical equipment, diagnostic capabilities, and treatments to improve warfighter performance and resilience. ONR develops solutions for point of injury care and casualty evacuation, new approaches to mitigate risks associated with operations in extreme environments such as dive medicine, and continues to address noise induced hearing loss by reducing noise at the source, limiting exposure, and developing protective technologies.

ONR's biological research program exploits principles from nature to design, control and power autonomous systems; improve processes, materials and sensors; and develop synthetic biology tools to support the Fleet/Force. Biocentric technologies offer a variety of enabling capabilities, including bio-inspired autonomous vehicles, acoustic/seismic discrimination systems, microbial fuel cells for sustainable power, engineered plants that produce energetic material precursors, and diagnostic tools to assess the health of marine mammals.

Human subject research is critical to support the Navy and Marine Corps warfighter, training and operational capability, and Navy Medicine. Many RDT&E activities designed to respond to Fleet/Force requirements necessitate human subject participation. As part of the DoN Human Research Protection Program, ONR is responsible for implementation of human subject protections in the Navy's systems commands, operational forces, training units, and at Navy-sponsored extramural institutions. ONR reconciles the competing priorities of conducting potentially risky research involving human subjects and compliance with federal, DoD, and DoN human protection policies.

Naval Air Warfare and Weapons

ONR's Naval Air Warfare goal is to develop, demonstrate and transition technologies to expand Naval weapon system stand-off ranges and reduce engagement timelines to enable rapid, precise, assured defeat of moving land, sea and air targets. We invest in S&T to develop propulsion for high speed weapons requiring technologies associated with high acceleration, high temperature, and high strength materials. We develop advanced structural materials and corrosion protection for aircraft, improvements that enhance operational characteristics such as improved lift, and to address other requirements driven by operations in the unique maritime environment. These include kinematic and lethality enhancements to increase range and effectiveness of tactical

weapons, and aided target recognition to provide the F/A-18 with advanced target identification capabilities.

Naval Research Laboratory (NRL)

ONR supports the DoN corporate lab, the Naval Research Laboratory (NRL). The NRL base program develops S&T to meet needs identified in the Naval S&T Strategic Plan and sustains world class skills and innovation in our in-house laboratory. Research at NRL is the foundation that can focus on any area to develop technology from concept to operation when high-priority, short-term needs arise. NRL is the lead Navy lab for space systems, firefighting, tactical electronic warfare, advanced electronics and artificial intelligence. Among our greatest challenges is to recapitalize NRL infrastructure. I invite you to visit this facility and learn more about research undertaken there by our world-class scientists and engineers.

ONR Global

ONR has offices in London, Prague, Singapore, Tokyo and Santiago – and closely coordinates activities with the other services and Assistant Secretary of Defense (Research and Engineering). We search for emerging research and technologies to help address current Naval needs, as well as requirements for future capabilities. ONR Global establishes contacts with international S&T leaders, giving us new perspectives and helping identify trends and forecast threats. It enables us to recruit the world's scientists and engineers in partnerships to benefit the U.S. and our allies. Global includes Science Advisors who communicate Fleet/Force needs to the Naval Research Enterprise (primarily Navy labs, warfare centers, affiliated universities) to facilitate development of solutions to transition to the Fleet/Force. Participants include Naval engineers who coordinate experimentation, develop prototypes, define transition options, and collaborate with Fleet/Force to define S&T investments. Our International Science Program gives scientists from academia, government and industry opportunities to engage leading international scientists and innovators. Our technical staff helps establish collaboration between Naval scientists and their foreign counterparts, and identifies centers of excellence for Naval S&T.

Conclusion

The FY 2015 President's Budget request will enable us to continue moving toward enhanced capabilities, more effective partnership between research and acquisition, and strengthened partnerships with the Army, Air Force, DARPA and other DoD research organizations – as well as performers outside the Naval R&D system. We strive to tap into the full spectrum of discovery and accelerate the transition of appropriate technologies to civilian use. Our S&T investments represent careful stewardship of taxpayer dollars that will achieve these goals and significantly enhance the safety and performance of warfighters as they serve in defense of the United States. Thank you for your support.

United States Navy
Biography

Rear Admiral Matthew L. Klunder
Chief of Naval Research/Director, Innovation, Technology Requirements, and Test & Evaluation (N84)

Rear Adm. Klunder, a native of Alexandria, Va., graduated from the United States Naval Academy in 1982 and earned his wings of gold at Meridian, Miss., in September 1984. Subsequent flying tours were based in Naval Air Station (NAS) Miramar, Calif.; NAS Patuxent River, Md.; Naval Air Facility Atsugi, Japan; and NAS Lemoore, Calif., where he was qualified in numerous aircraft including the E-2C Hawkeye and F/A-18 E/F Super Hornet.

Klunder has served at sea in Airborne Early Warning Squadron (VAW) 112; VAW-115 as a department head, and as commanding officer; and Carrier Air Wing Two as air wing commander. He has made eight deployments and multiple surge operations to the Atlantic, Pacific and Indian oceans and to the Mediterranean Sea and Arabian Gulf.

Klunder's shore tours include serving as a flight instructor, Naval Air Training and Operating Procedures Standardization officer and Commander Naval Air Force, U.S. Pacific Fleet evaluator at VAW-110; test pilot/project officer at Force Warfare Test Directorate; senior operations officer and Single Integrated Operational Plan officer at the Joint Staff J-3/National Military Command Center; Joint Staff liaison officer and section chief at the U.S. State Department; Combined Air Operations Center deputy director at Al Udeid Air Base in Qatar; deputy director for Information, Plans, and Security for OPNAV N3/N5; 83rd commandant of Midshipmen at the U.S. Naval Academy; and director of Intelligence, Surveillance and Reconnaissance Capabilities Division, OPNAV N2/N6F2. Highlights during these tours include receiving the 1988 Hawkeye of the Year award, the 1991 Test Pilot of the Year award, and the 2002 George C. Marshall Statesman award.

In November 2011, he became the 24th Chief of Naval Research, with additional duties as director, Test Evaluation and Technology Requirements.

Klunder received his bachelor's degree from the U.S. Naval Academy, a master's degree in Aerodynamics and Aviation Systems from the University of Tennessee, and a master's degree in Strategic Studies from the National War College.

He has flown more than 45 different aircraft and accumulated 21 world-flying records. His awards include the Legion of Merit (four Awards), Defense Meritorious Service Medal (two Awards), Meritorious Service Medal (two Awards), Joint Commendation Medal (two Awards), Navy and Marine Corps Commendation Medal (four Awards) and various unit and campaign awards.

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HOUSE ARMED SERVICES COMMITTEE
SUBCOMMITTEE ON INTELLIGENCE, EMERGING THREATS AND CAPABILITIES
U.S. HOUSE OF REPRESENTATIVES

DEPARTMENT OF THE AIR FORCE

PRESENTATION TO THE HOUSE ARMED SERVICES COMMITTEE
SUBCOMMITTEE ON INTELLIGENCE, EMERGING THREATS AND CAPABILITIES

U.S. HOUSE OF REPRESENTATIVES

26 March, 2014

SUBJECT: Fiscal Year 2015 Air Force Science and Technology

STATEMENT OF: Dr. David E. Walker, SES
Deputy Assistant Secretary
(Science, Technology and Engineering)

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INTRODUCTION

Chairman Thornberry, Ranking Member Langevin, Members of the Subcommittee and Staff, I am pleased to have the opportunity to provide testimony on the Fiscal Year 2015 Air Force Science and Technology (S&T) Program, especially during this unprecedented time in our history.

Our Nation is one of a vast array of actors in a complex, volatile, and unpredictable security environment. Globalization and the proliferation of technology mean we face threats across a wide spectrum and competition across all domains. We're confronted by ever-evolving adversaries ranging from one person with a single interconnected computer to sophisticated capable militaries and everything in between. We're also challenged by the shear pace of change among our adversaries fueled by profound information and technology diffusion worldwide. As stated by the Chief of Staff of the Air Force in the *Global Vigilance, Global Reach and Global Power For Our Nation* vision, "despite the best analyses and projections by national security experts, the time and place of the next crisis are never certain and are rarely what we expect." Success and the guaranty of security in this dynamic environment require that we both take lessons learned from the last decade of conflict and creatively visualize the future strategic landscape. It's in this space, between learning from the past and keeping an open eye to the future, where we find opportunity.

The focused and balanced investments of the Air Force Fiscal Year 2015 S&T Program are hedges against the unpredictable future and provide pathways to a flexible, precise and lethal force at a relatively low cost in in relation to the return on investment. The Undersecretary of Defense for Acquisition, Technology and Logistics recently reminded us that complacency now and in the future is simply not an option. Maintaining, and even expanding, our technological advantage is vital to ensuring sustained freedom of access and action in air, space and cyberspace.

AIR FORCE FISCAL YEAR 2015 S&T PROGRAM

The Air Force as a whole had to make difficult trades between force structure (capacity), readiness, and modernization (capability) in the Service's Fiscal Year 2015 President's Budget submission to recover from budget uncertainty over the two previous fiscal years. The Air Force Fiscal Year 2015 President's Budget request for S&T is approximately $2.1 billion, which includes nearly $178 million in support of devolved programs consisting of High Energy Laser efforts and the University Research Initiative. This year's Air Force S&T budget request represents a decrease of $141 million or a 6.2% decrease from the Fiscal Year 2014 President's Budget request, a slightly larger reduction as compared to the overall Air Force topline reduction. This budget request re-balances basic research spending as part of the overall portfolio to increase emphasis on conducting technology demonstrations. The Air Force was able to reduce funding in the aerospace systems and materials areas while still advancing capabilities for the Air Force and the Department of Defense (DoD) by smartly leveraging research being conducted by the Defense Advanced Research Projects Agency (DARPA) in the hypersonics area.

We've learned a great deal over the last decade. The dedicated scientists and engineers of the Air Force Research Laboratory (AFRL) have successfully supported warfighters during conflicts in Iraq, Afghanistan, and North Africa through the rapid development of systems and capabilities including persistent intelligence, surveillance, and reconnaissance (ISR); data fusion and integration from multiple sensors; and near real-time monitoring of some orbiting U.S. and commercial spacecraft assets. With the pivot to the Pacific as outlined in the *Defense Strategic Guidance*, we must continue to evolve and advance "game-changing" and enabling technologies which can transform the landscape of how the Air Force flies, fights and wins against the high-end threats in contested environments envisioned in the future.

In close coordination with the requirements, intelligence and acquisition communities, we have structured our Air Force Fiscal Year 2015 S&T Program to address the highest priority needs of the Air Force across the near-, mid- and far-term; execute a balanced and integrated program that is responsive to Air Force core missions; and advance critical technical competencies needed to address the full range of product and support capabilities. The Air Force continues to focus efforts to deliberately align S&T planning, technology transition planning, development planning and early systems engineering. The linkages between these planning activities are critical to initiating acquisition programs with more mature technologies and credible cost estimates, and we are institutionalizing these linkages in Air Force policy. Air Force S&T provides critical inputs at several phases of the Chief of Staff of the Air Force's *Air Force 2023* strategic planning effort including helping to shape the "realm of the possible" when envisioning long term strategy, offering technologies to expand the strategic viewpoint and identifying potential solutions to requirements and capability gaps. Our forthcoming updated Air Force S&T strategy focuses on investing in S&T for the future, as well as leverages our organic capacity, and the capacity of our partners (domestic and international), to integrate existing capabilities and mature technologies into innovative, affordable, and sustainable solutions. This flexible strategy provides us the technological agility to adapt our S&T Program to dynamic strategic, budgetary, and technology environments and will shape prioritized actionable S&T plans.

NEAR TERM TECHNOLOGY TRANSITION

The Air Force continues to move our Flagship Capability Concept (FCC) projects toward transition to the warfighter. A well-defined scope and specific objectives desired by a Major Command (MAJCOM) are key factors in commissioning this type of an Air Force-level technology demonstration effort. The technologies are matured by the Air Force Research Laboratory with the intent to transition to the acquisition community for eventual deployment to an end user. These

FCCs are sponsored by the using MAJCOM and are vetted through the S&T Governance Structure and Air Force Requirements Oversight Council to ensure they align with Air Force strategic priorities. In Fiscal Year 2014, the Air Force successfully completed and transitioned the Selective Cyber Operations Technology Integration (SCOTI) FCC and will continue work on the High Velocity Penetrating Weapon (HVPW) and Precision Airdrop (PAD) FCCs.

AFRL delivered the SCOTI FCC to the Air Force Life Cycle Management Center (AFLCMC) in September 2013, on time, on budget and within specification. SCOTI consists of cyber technologies capable of affecting multiple nodes for the purposes of achieving a military objective and gaining cyberspace superiority. SCOTI's robust, modular architecture provides vital extensibility to allow cyber warriors to keep pace with rapidly evolving threats. AFLCMC is evaluating the delivered SCOTI architecture for integration with operational cyber mission software to directly meet the needs of a major capability area in the Air Force Cyberspace Superiority Core Function Master Plan. By successfully meeting the requirements of the stakeholder-approved Technology Transition Plan, SCOTI is the first FCC to transition and will serve as a baseline for current and future integrated cyber tools to provide needed effects for the warfighter.

The HVPW FCC was established to demonstrate critical technologies to reduce the technical risk for a new generation of penetrating weapons to defeat difficult, hard targets. This FCC matures technologies that can be applied to the hard target munitions acquisition including guidance and control, terminal seeker, fuze, energetic materials and warhead case design. This effort develops improved penetration capability of hard, deep targets containing high strength concrete with up to 2,500 feet per second (boosted velocity) impact in a GPS-degraded environment. This technology will demonstrate penetration capability of a 5,000 pound-class gravity weapon with a 2,000 pound weapon thus enabling increased loadout for bombers and fighters. Tests will demonstrate complete warhead functionality, and are scheduled to be completed the end of September 2014.

The PAD FCC was commissioned in response to a request from the Commander of Air Mobility Command for technologies to improve airdrop accuracy and effectiveness while minimizing risk to our aircrews. To date, PAD FCC efforts have focused on: early systems engineering analysis to determine major error sources, data collection, flying with crews, wind profiling, bundle tracking, and designing modeling and simulation activities. The Air Force Research Laboratory completed the bundle tracker development in Fiscal Year 2013 and in Fiscal Year 2014 began wind profile sensor development.

GAME-CHANGING TECHNOLOGIES

The Air Force S&T Program provides technology options to enable operations in anti-access, area-denial environments and transform the way we fly, fight and win in air, space and cyberspace. To illustrate how, I will highlight some of our efforts in game-changing and enabling technology areas:

Hypersonics

Speed provides options for engagement of time sensitive targets in anti-access/area-denial environments, and improves the survivability of Air Force systems. Hypersonic speed weapons are also a force multiplier as fewer are required to defeat difficult targets and fewer platforms are required from greater standoff distances. The Air Force S&T community continues to execute the high speed technology roadmaps developed with industry over the last three years. We are also building on the success of the X-51A Waverider scramjet engine hypersonic demonstrator, which on 1 May 2013 reached an approximate Mach Number of 5.1 during its fourth and final flight. The Air Force has focused multi-faceted, phased investments in game-changing technology for survivable, time-critical strike in the near term and a penetrating regional intelligence, surveillance, and reconnaissance (ISR) and strike aircraft in the far term.

The near term strike effort is the High Speed Strike Weapon (HSSW) program. This effort will mature cruise missile technology to address many of those items necessary to realize a missile in the hypersonic speed regime including: modeling and simulation; ramjet/scramjet propulsion; high temperature materials; guidance, navigation, and control; seekers and their required apertures; warhead and subsystems; thermal protection and management; manufacturing technology; and compact energetic booster technologies.

The Air Force conducts research and development in all aspects of hypersonic technologies in partnership with NASA, DARPA, and industry/academic sectors. The HSSW program will include two parallel integrated technology demonstration efforts to leverage DARPA's recent experience in hypersonic technologies that are relevant to reduce risk in key areas. One of the demonstrations will be a tactically-relevant demonstration of an air breathing missile technology that is compatible with Air Force 5th generation platforms including geometric and weight limits for internal B-2 Spirit bomber carriage and external F-35 Lightening II fighter carriage. This demonstration will build on the X-51 success and will include a tactically compliant engine start capability and launch from a relevant altitude.

For the other demonstration, the Air Force and DARPA will seek to develop technologies and demonstrate capabilities that will enable transformational changes in prompt, survivable, long-range strike against using the Tactical Boost Glide (TBG) concept. The objective of the TBG effort is to develop and demonstrate the critical technologies that will enable an air launched tactical range, hypersonic boost-glide missile. Both efforts will build upon experience gained through recent hypersonic vehicle development and demonstration efforts supported by DARPA and the Air Force. These demonstrations are traceable to an operationally relevant weapon that could be launched from existing aircraft. Technology and concepts from these efforts will provide options

for an operational weapon system for rapidly and effectively prosecuting targets in highly contested environments.

Autonomy

Analysis of these future operating environments has also led the Air Force to invest in game-changing advances in autonomous systems. Autonomous systems can extend human reach by providing potentially unlimited persistent capabilities without degradation due to fatigue or lack of attention. The Air Force S&T Program is developing technologies that realize true autonomous capabilities including those that advance the state-of-the-art in machine intelligence, decision-making, and integration with the warfighter to form effective human-machine teams.

The greater use of autonomous systems increases the capability of U.S. forces to execute well within the adversaries' decision loops. Human decision-makers intelligently integrated into autonomous systems enable the right balance of human and machine capability to meet Air Force challenges in the future. The Air Force S&T Program invests in the development of technologies to enable warfighters and machines to work together, with each understanding mission context, sharing understanding and situation awareness, and adapting to the needs and capabilities of the other. The keys to maximizing this human-machine interaction are: instilling confidence and trust among the team members; understanding of each member's tasks, intentions, capabilities and progress; and ensuring effective and timely communication. All of which must be provided within a flexible architecture for autonomy, facilitating different levels of authority, control and collaboration. Current research is focused on understanding human cognition and applying these concepts to machine learning. Efforts develop efficient interfaces for an operator to supervise multiple unmanned air systems (UAS) platforms and providing the ISR analyst with tools to assist identifying, tracking, targets of interest.

Autonomy also allows machines to synchronize activity and information. Systems that coordinate location, status, mission intent, and intelligence and surveillance data can provide redundancy, increased coverage, decreased costs and/or increased capability. Research efforts are developing control software to enable multiple, small UASs to coordinate mission tasking with other air systems or with ground sensors. Other research efforts are developing munition sensors and guidance systems that will increase operator trust, validation, and flexibility while capitalizing on the growing ability of munitions to autonomously search a region of interest, provide additional situational awareness, plan optimum flight paths, de-conflict trajectories, optimize weapon-to-target orientation, and cooperate to achieve optimum effects.

Finally, before any system is fielded, adequate testing must be conducted to demonstrate that it meets requirements and will operate as intended. As technologies with greater levels of autonomy mature, the number of test parameters will increase exponentially. Due to this increase, it will be impractical to verify and validate autonomous system performance, cost-effectively, using current methods. The Air Force is developing test techniques that verify the decision-making and logic of the system and validate the system's ability to appropriately handle unexpected situations. Efforts are focused at the software-level and build to overall system to verify codes are valid and trustworthy. The Air Force will demonstrate the tools needed to ensure autonomous systems operate safely and effectively in unanticipated and dynamic environments.

Directed Energy

With a uniquely focused directorate within AFRL, the Air Force is in a leading position in the game-changing area of directed energy. These technologies, including high powered microwave (HPM) and high energy lasers (HELs), can provide distinctive and revolutionary capabilities to several Air Force and joint mission areas. Laser technologies are rapidly evolving for infrared seeker jamming, secure communications in congested and jammed spectrum

environments, space situational awareness, and vastly improved ISR and target identification capabilities at ever increasing ranges. To get HELs to a weapon system useful to the Air Force, our S&T program invests in research in laser sources from developing narrow line width fiber lasers to scaling large numbers of fiber lasers with DARPA and MDA. Since HEL devices are not sufficient for a weapon, the Air Force directed energy research also includes beam control, atmospheric compensation, acquisition, pointing, tracking, laser effects, and physics based end-to-end modeling and simulation. The Air Force also funds the High Energy Laser Joint Technology Office (HEL JTO) which supports all of the services by being the key motivator of high power laser devices such as the successful 100 kilowatt, lab-scale Joint High Power Solid State Laser (JHPSSL) and other funding many smaller successes. The current primer program, which is jointly funded with core Army and Air Force funds, is the Robust Electric Laser Initiative (RELI). The initiative funds efforts to develop designs for efficient and weaponizable solid state lasers with options leading to a 100 kilowatt laser device.

Our HPM S&T will complement kinetic weapons to engage multiple targets, neutralizing communication systems, computers, command and control nodes, and other electronics, with low collateral damage for counter-anti-access/area denial in future combat situations. The Air Force is using the results of from the highly successful Counter-Electronics High Power Microwave Advanced Missile Project (CHAMP) Joint Capabilities Technology Demonstration (JCTD) to inform an effort known as Non-Kinetic Counter Electronics (NKCE). NKCE is currently in pre-Alternative of Alternatives (AoA) phase, with an AoA potentially starting in Fiscal Year 2015. The AoA will examine the cost and performances for kinetic, non-kinetic, and cyber options for air superiority and seeks to have a procured and operational weapon system to support the targets and requirements of the Combatant Commanders in the mid-2020 time frame. In parallel, the Air Force

S&T Program is continuing HPM research and development to provide a more capable and smaller counter-electronics system that can fit onto a variety of platforms.

The DoD directed energy research community is highly integrated and the Air Force leverages the work of other agencies. For example, the Air Force is working with the Missile Defense Agency on integrated electro-optical/infrared pulsed-laser targeting to enhance situational awareness and increase survivability by enabling the use of legacy weapons in the 2016 timeframe. In addition, the Air Force is partnering with DARPA on the Demonstrator Laser Weapon System, a ground-based fully integrated laser weapon system demonstration over the next two fiscal years and an Air-to-Air Defensive Weapon Concept.

Fuel Efficiency Technologies

For the longer term reduction in energy demand, the Air Force is investing in the development of adaptive turbine engine technologies which have the potential to reduce fuel consumption while also increasing capability in anti-access/area denial environments through increased range and time-on-station. The Air Force has several priority efforts as part of the DoD's Versatile Advanced Affordable Turbine Engine (VAATE) technology program. VAATE is a coordinated Army, Navy, and Air Force plan initiated in 2003 to develop revolutionary advances in propulsion system performance, fuel efficiency and affordability for the DoD's turbine engine powered air platforms.

The initial effort, Adaptive Versatile Engine Technology (ADVENT), began in fiscal year 2007 and is set to complete this year. General Electric is currently in final testing of the ADVENT engine technologies which include a next generation high pressure ratio core and an adaptive fan in a third stream engine architecture.

The Adaptive Engine Technology Development (AETD) program, our accelerated follow-on adaptive engine effort for the combat Air Force, is progressing very well. The objective of

AETD is to fully mature adaptive engine technologies for low risk transition to multiple combat aircraft alternatives ready for fielding as soon as the early 2020's. The effort will deliver a preliminary prototype engine design, substantiated by major hardware demonstrations, that can be tailored to specific applications when the DoD is ready to launch new development programs. The overarching goal of AETD is to mature adaptive engine technologies so that these programs can launch with significantly lower risk than previous propulsion development programs.

The High Energy Efficient Turbine Engine (HEETE) S&T effort is our flagship large engine effort under the VAATE technology program. The HEETE effort's primary objective is to demonstrate engine technologies that enable a 35% fuel efficiency improvement versus the VAATE year 2000 baseline, or at least 10% beyond current VAATE technology capabilities being demonstrated in the ADVENT program.

The Air Force Research Laboratory and industry have conducted a number of HEETE payoff studies that show significant potential benefits to future transport and ISR aircraft (e.g., 18% to 30% increase in strategic transport range, 45% to 60% increase in tactical transport radius, and 37% to 75% increase in ISR UAV loiter time). A study of Air Force's fleet fuel usage showed that introduction of HEETE-derived engines into the mobility and the tanker fleet would enable fuel savings of approximately 203 million gallons per year by the mid-2030's.

Investments in these efforts help us reduce energy demand, bridge the "valley of death" between S&T and potential acquisition programs, and help maintain the U.S. industrial technological edge and lead in turbine engines.

ENABLING TECHNOLOGIES

In addition to these game-changing technologies, the Air Force S&T Program also invests in many enabling technologies to facilitate major advances and ensure maximum effectiveness in the near-, mid-, and far term:

Cyber

Operations in cyberspace magnify military effects by increasing the efficiency and effectiveness of air and space operations and by helping to integrate capabilities across all domains. However, the cyberspace domain is increasingly contested and/or denied and the Air Force faces risks from malicious insiders, insecure supply chains, and increasingly sophisticated adversaries. Fortunately, cyberspace S&T can provide assurance, resilience, affordability, and empowerment to enable the Air Force's assured cyber advantage.

In 2012, the Air Force developed *Cyber Vision 2025* which described the Air Force vision and blueprint for cyber S&T spanning cyberspace, air, space, command and control, intelligence, and mission support. *Cyber Vision 2025* provides a long-range vision for cyberspace to identify and analyze current and forecasted capabilities, threats, vulnerabilities and consequences across core Air Force missions in order to identify key S&T gaps and opportunities. The Air Force's cyber S&T investments for Fiscal Year 2015 are aligned to the four themes identified in *Cyber Vision 2025*: Mission Assurance, Agility and Resilience, Optimized Human-Machine Systems, and Foundations of Trust.

Air Force S&T efforts in Mission Assurance seek to ensure survivability and freedom of action in contested and denied environments through enhanced cyber situational awareness for air, space, and cyber commanders. Current research efforts seek to provide dynamic, real-time mapping and analysis of critical mission functions onto cyberspace. This analysis includes the cyber situation awareness functions of monitoring the health and status of cyber assets, and extends to capture how missions flow through cyberspace. This work seeks to provide commanders with the ability to recognize attacks and prioritize defensive actions to protect assets supporting critical missions. Other research efforts develop techniques to measure and assess the effects of cyber operations and integrate them with cross-domain effects to achieve military objectives.

Research in Agility and Survivability develops rapid and unpredictable maneuver capabilities to disrupt the adversaries' cyber "kill chain" along with their planning and decision-making processes and hardening cyber elements to improve the ability to fight through, survive, and rapidly recover from attacks. Air Force S&T efforts are creating dynamic, randomizable, reconfigurable architectures capable of autonomously detecting compromises, repairing and recovering from damage, and evading threats in real-time. Cyber resiliency is enhanced through an effective mix of redundancy, diversity, and distributed functionality that leverages advances in virtualization and cloud technologies.

The Air Force works to maximize the human and machine potential through the measurement of physiological, perceptual, and cognitive states to enable personnel selection, customized training, and (user, mission, and environment) tailored augmented cognition. S&T efforts develop visualization technologies to enable a global common operational picture (COP) of complex cyber capabilities that can be readily manipulated to support Air Force mission-essential functions (MEFs). Other efforts seek to identify the critical human skills and abilities that are the foundation for superior cyber warriors and develop a realistic distributed network training environment integrated with new individualized and continuous learning technologies.

The Air Force is developing secure foundations of computing to provide operator trust in Air Force weapon systems that include a mix of embedded systems, customized and militarized commercial systems, commercial off-the-shelf (COTS) equipment, and unverified hardware and software that is developed outside the United States. Research into formal verification and validation of complex, large scale, interdependent systems as well as vulnerability analysis, automated reverse engineering, and real-time forensics tools will enable designers to quantify the level of trust in various components of the infrastructure and to understand the risk these components pose to the execution of critical mission functions. Efforts to design and build secure

hardware will provide a secure root-of-trust and enable a more intelligent mixing of government off-the-shelf (GOTS) and COTS components based on the systems' security requirements.

Cognitive Electronic Warfare

With the highly contested future EW environment, we have focused S&T efforts on creating the ability to rapidly respond to threats. This is accomplished by developing the analytic ability to understand a complex threat environment and determine the best combination of techniques across all available platforms. In addition, leveraging cognitive and autonomy concepts improves the cycle time between emergence of a threat and development of an effective response. This system-of-systems solution approach is implemented in a physics based interactive simulation capability to evaluate novel concepts. The Air Force is also developing technologies to enhance survivability and improve situational awareness in the electro-optical (EO)/infrared (IR) and radio frequency (RF) warning and countermeasures area. New electronic components (antennas, amplifiers, processors) will improve the ability to detect threats with emphasis on advanced processing and software to assess threats in a crowded RF environment. This includes solutions to detect and defeat infrared and optical threats. These will enable protection against autonomous seekers using multi-spectral tracking.

Space Situational Awareness / Space Control

The ability to counter threats, intentional or unintentional, in the increasingly congested and contested space domain begins with Space Situational Awareness (SSA). The SSA S&T investments needed to maintain our core Space Superiority and Command and Control missions in such an environment are substantial and include research in Assured Recognition and Persistent Tracking of Space Objects, Characterization of Space Objects and Events, Timely and Actionable Threat Warning and Assessment, and Effective Decision Support through Data Integration and

Exploitation. The Air Force works across these areas in cooperation with the DoD, intelligence community, and industry.

To help build a holistic national SSA capability, the Air Force's S&T investment is designed to exploit our in-house expertise to innovate in areas with short-, mid- and long-term impact that are not already being addressed by others. Examples include working with Federally Funded Research and Development Centers (FFRDCs) and academia to attack the deep space uncorrelated target association problem to improve custody of space objects and reduce the burden on the space surveillance network; better conjunction assessment and re-entry estimation algorithms to reduce collision probabilities and unnecessary maneuvers; and infrared star catalog improvement to ease observation calibrations. These products have recently transitioned to national SSA capabilities. Advanced component technologies developed with industry include visible focal plane arrays, deployable baffles and lenses to meet performance, and cost and weight requirements for future space-based surveillance systems.

As part of the Air Force Research Laboratory's long history of proving new technologies in relevant environments, the Automated Navigation and Guidance Experiment for Local Space (ANGELS) program examines techniques to provide a clearer picture of the environment around our vital space assets through safe, automated spacecraft operations above Geosynchronous Earth Orbit (GEO). Equipped with significant detection, tracking and characterization technology, ANGELS will launch in 2014. It will maneuver around its booster's upper stage and explore increased levels of automation in mission planning and execution, enabling more timely and complex operations with reduced footprint. Additional indications and warning work focuses on change detection and characterization technologies to provide key observables that improve response time and efficacy.

Satellite Resilience

Our Nation and our military are heavily dependent on space capabilities. With an operational space domain that is becoming increasingly congested, competitive and contested, the Air Force has seen the need for development of technologies to increase resilience of our space capabilities. The satellites upon which we rely so heavily must be able to avoid or survive threats, both man-made and natural, and to operate through and subsequently quickly recover should threat or environmental effects manifest. To this end, the Air Force S&T Program has increased technological investment in tactical sensing and threat warning, reactive satellite control, and hardening.

Satellites today are equipped with a wide range of sensors, that, if exploited in new ways and/or coupled with new hosted threat sensing technologies could yield significant increases to tactical sensing and threat warning. The Air Force pursues a range of internally-focused health and status sensing (e.g. structural integrity, thermal, cyber) and externally focused object or phenomena sensing (e.g. space environment, threat sensing, directed energy detection) technologies, and a range of data fusion approaches to maximize the timeliness and confidence of that warning. While tactical warning is vital, it is only immediately helpful when a satellite is able to tactically respond in some way to avoid a threat or minimize its effects. Any choice of a response requires some means of reconciling warning with viable courses of action available. The Air Force focuses on efforts specifically dedicated to tailoring satellite control based on tactical warning inputs. Finally, hardening technologies refers to a range of both passive and active capabilities that, when selected and executed, could result in threat avoidance, lessening their effects or recovering lost capability more quickly. For example, for particular types of threats, dynamic configuration changes, optical protection, cyber quarantine, dynamic thermal management or possibly maneuvers might achieve the desired protection.

Precision Navigation and Timing (PNT)

Most U.S. weapon systems rely on the Global Positioning System (GPS) satellites to provide the required position navigation and timing (PNT) to function properly. This reliance has created a vulnerability which is being exploited by our adversaries through development of jammers to degrade access to the GPS signals. For success in the long term, Air Force S&T is improving the robustness of military GPS receivers and also developing several non-GPS based alternative capabilities including exploitation of other satellite navigation constellations, use of new signals of opportunity, and incorporation of additional sensors such as star trackers and terrain viewing optical systems. These receivers provide new navigation options with different accuracy depending on available sensors and computational power. Rapid progress is being made on advanced Inertial Measurement Units based on cold atom technologies. These units have the potential to provide accurate PNT for extended periods without any external update. Together, these approaches will provide future options to enable the Air Force mission to continue in contested and denied environments.

Assured Communications

Assured communications are critical to the warfighter in all aspects of the Air Force core missions. The Air Force S&T Program is developing technologies to counter threats to mission performance, such as spectrum congestion and jamming, and to maintain or increase available bandwidth through access to new portions of the radio frequency spectrum, alleviating pressure on DoD spectrum allocations. Future ability to use new spectrum will increase DoD communications architecture capacity and affordability, by requiring fewer expensive, high capacity gateways. Additional bandwidth will allow improved anti-jam communications performance and higher frequency communications, which will reduce scintillation losses for nuclear command and control

(C2). The performance enhancements would directly improve the ability of remotely-piloted aircraft to transmit images and data (ISR) and improve command and control assurance.

Efforts in Assured Communications include the Future Space Communications effort which includes research to characterize and provide new spectrum for future military space communications through the W/V-band Space Communications Experiment (WSCE). WSCE will characterize and model the atmospheric effects of upper V-band and W-band (71-76 GHz and 81-86 GHz) signal transmission. Space-based data collection and atmospheric attenuation model development is necessary to provide the statistics necessary to design a future satellite communications architecture that will allow use of the currently empty V- and W-band spectrum.

Long Range Sensing

For the past decade the Air Force has provided near persistent ISR for Combatant Commanders conducting operations in the uncontested air environments of Iraq and Afghanistan. We do not see the appetite for ISR waning in the future. However, the ability to perform effective sensing in anti-access/area denial and contested environments is threatened by many new and different challenges rarely seen during the past 10 years of permissive environment operations. In the past, airborne collection platforms conducted airborne ISR outside of the lethal range of air defense systems. Today, however, the modern and evolving foreign Integrated Air Defense Systems (IADS) of our adversaries have increased lethality and significantly improved engagement capabilities which will force ISR aircraft to fly at longer stand-off distances. The effectiveness of current precision weapons will be reduced with distance limiting the ability to accurately detect, identify and geo-locate targets.

The Air Force S&T Program is focused on significantly improving our sensing ability to adequately address the challenges of extended range ISR collection. The efforts include: 1) next generation RF sensing for contested spectrum environments in which long stand-off sensing is

primarily focused on all-weather ISR using traditional active radar modes at ranges of greater than 100 miles; 2) passive RF Sensing in which signals of opportunity are exploited to detect, identify and locate targets through the use of passive multi-mode and distributed multi-static techniques; 3) laser radar sensing focused on enhancing target identification through the use of synthetic aperture laser radar and also addressing high resolution wide-area three dimensional imaging through advancements in direct detection ladar; and 4) passive EO/IR sensing to enhance capabilities to detect and track difficult targets, improve target identification at long standoff ranges and perform material identification through advancing hyperspectral and stand-off high resolution imaging technology.

Live, Virtual, and Constructive (LVC)

The Air Force continues to develop and demonstrate technologies for Live, Virtual, and Constructive (LVC) operations to maintain combat readiness. The training need for LVC is real while training costs are increasing and threat environments are complex. In particular, realistic training for anti-access/area-denial environments is not available. During a recent demonstration of LVC capability for tactical forces at Shaw AFB, South Carolina, AFRL LVC research capability was integrated in operations with an F-16 Unit Training Device (a virtual simulator) to simultaneously interoperate with a mix of live F-16 aircraft, other virtual simulations, and high fidelity computer-generated constructive players. This mix of players enabled the real time and realistic portrayal and interaction of other strike package assets and aggressor aircraft with a level of complexity that could not be achieved if limited to live assets, given the expense and availability of them to support the scenarios. LVC S&T has the capability to provide greater focused training for our warfighters across a range of operational domains such as tactical air, special operations, cyber, ISR, and C2. The Air Force is exploring a 5th generation LVC Proof of Concept set of demonstrations that would validate the requirements for a formal program of record for LVC.

Basic Research

The development of revolutionary capabilities requires the careful investment in foundational science to generate new knowledge. Our scientists discover the potential military utility of these new ideas and concepts, develop this understanding to change the art-of-the-possible and then transition the S&T for further use. Air Force basic research sits at the center of an innovation network that tracks the best S&T in the DoD, with our partners in the Army, the Navy, DARPA, and the Defense Threat Reduction Agency (DTRA), while monitoring the investments and breakthroughs of the NSF, NASA, NIST, and the Department of Energy. Air Force scientists and engineers watch and collaborate with the best universities and research centers from around the world in open, publishable research that cuts across multiple scientific disciplines aligned to military needs.

For example, Air Force basic research played a role in the Air Force's successful CHAMP technology demonstration discussed earlier. While the CHAMP demonstration required extensive applied research and advanced technology development, fundamental basic research investment in both supercomputers and computational mathematics provided a virtual prototyping capability called Improved Concurrent Electromagnetic Particle-In-Cell (ICEPIC) for directed energy concepts to Air Force researchers. This allowed new ideas to be studied effectively and affordably on the computer without costly manufacture for every iteration of the technology. Virtual prototyping was a critical enabling technology, and resulted from nearly two decades of steady, targeted investments in fundamental algorithms that then transitioned to a capability driving technology development in Air Force laboratories and in industry.

Manufacturing Technologies

A key cross-cutting enabling technology area is in developing materials, processes, and advanced manufacturing technologies for all systems including aircraft, spacecraft, missiles, rockets, ground-based systems and their structural, electronic and optical components. The fiscal year 2015 Air Force S&T Program emphasizes materials work from improved design and manufacturing processes to risk reduction through assessing manufacturing readiness.

The Air Force's investment in additive manufacturing technologies offers new and innovative approaches to the design and manufacture of Air Force and DoD systems. Additive manufacturing, or the process of joining materials to make objects from 3D model data layer by layer, changes the conventional approach to design, enabling a more direct design to requirements. As opposed to subtractive processes like machining, additive manufacturing offers a whole new design realm in which geometric complexity is not a constraint and material properties can be specifically located where needed. As with the insertion of all advanced materials and processes, the Air Force strives to ensure appropriate application and proper qualification of additive manufacturing for warfighter safety and system performance.

Currently, the Air Force is invested in more than a dozen programs ranging from assisting in major high-Technology Readiness Level (TRL) qualification programs to mid-TRL process improvement programs, to low-TRL process modeling and simulation programs. Overall, we have established a strategic program to quantify risk for implementation and to advance the understanding of processing capabilities. We have identified multiple technical areas that require Air Force investment and are developing an initiative that integrates pervasive additive manufacturing technologies across Air Force sectors, spanning multiple material classes from structural, metallic applications to functional, electronic needs.

The Air Force leverages its additive manufacturing resources and interests with the Administration's National Network for Manufacturing Innovation (NNMI) to support the acceleration of additive manufacturing technologies to the U.S. manufacturing sector to increase domestic competitiveness. In fiscal year 2013, the Air Force played a key role in supporting the NNMI National Additive Manufacturing Innovation Institute called "America Makes." The Air Force, on behalf of the Office of the Secretary of Defense, led an interagency effort , which included DoD, DOE, DOC/NIST, NASA, and NSF, to launch a $69 million public-private partnership in Additive Manufacturing.

Cooperatively working with the private partner team lead, the Air Force helped "America Makes" achieve significant accomplishments in its first year. After opening it headquarters in Youngstown, Ohio in September 2012, the "America Makes" consortium has grown to approximately 80 member organizations consisting of manufacturing companies, universities, community colleges, and non-profit organizations. A shared public-private leadership governance structure, organizational charter, and intellectual property strategy were implemented and two project calls were launched in Additive Manufacturing and 3D printing technology research, discovery, creation, and innovation. So far, more than 20 projects totaling approximately $29M and involving more than 75 partners have been started covering a broad set of priorities including advances in materials, design and manufacturing processes, equipment, qualification and certification, and knowledge base development. "America Makes" serves as an example for future NNMI institutes and the Air Force has provided support to establish two additional DoD sponsored institutes of manufacturing innovation.

The Air Force Manufacturing Technology program continues to lead the way in developing methods and tools for Manufacturing Readiness Assessments and continues to lead assessments on new technology, components, processes, and subsystems to identify manufacturing maturity and

associated risk. Increasing numbers of weapon system prime contractors and suppliers have integrated Manufacturing Readiness into their culture which aids in product and process transition and implementation, resulting in reduced cost, schedule and performance risk. Benefits from the advanced manufacturing propulsion initiative continue to accrue in the form of reduced turbine engine cost and weight through advanced manufacturing of light weight castings and ceramic composites and improved airfoil processing. Advanced next generation radar and coatings affordability projects continue to reduce cost and manufacturing risk to systems such as the F-22 and F-35 aircraft. The Air Force Manufacturing Technology investment continues to make a significant impact on the F-35 program in particular, driving down life cycle costs by over $3 billion, with a number of ongoing projects that will benefit multiple F-35 program Integrated Product Teams.

The Air Force is also leveraging basic research efforts to improve sustainment of legacy systems. The "Digital Twin" concept combines the state-of-the-art in computational tools, advanced sensors, and novel algorithms to create a digital model of every platform in the fleet. Imagine a world where instead of using fleet averages for the maintenance and sustainment of an airframe, there is a computer model of each plane that records all the data from each flight, integrates the stress of the flights into the history of the actual materials on the platform, and continually checks the health of vital components. Thus, the computer model mimics all the missions of the physical asset, thereby allowing us to do maintenance exactly when required. This is the airplane equivalent of individualized medicine, making sure that each individual asset of the Air Force is set to operate at peak performance. Interdisciplinary basic research in material science, fundamental studies in new sensors and novel inquiry into new, transformational computer architecture enable the Digital Twin concepts. These foundational studies are tightly integrated

with applied research, both in the Air Force Research Laboratory as well as efforts in NASA, to drive forward the S&T to permit breakthroughs in affordable sustainment.

RAPID INNOVATION PROGRAM AND SMALL BUSINESS INNOVATION RESEARCH

The Air Force recognizes small businesses are critical to our defense industrial base and essential to our Nation's economy. The U.S. relies heavily on innovation through research and development as the small businesses continue to be a major driver of high-technology innovation and economic growth in the U.S. We continue to engage small businesses through the Rapid Innovation Program, and the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.

The Rapid Innovation Program has been an excellent means for the Air Force to communicate critical needs and solicit vendors to respond with innovative technology solutions. The program provides a vehicle for businesses, especially small businesses, to easily submit their innovative technologies where they feel it will best meet military needs. The Air Force benefits from the ability to evaluate proposed innovative technologies against critical needs, and selecting the most compelling for contract award. The response to the program has been overwhelming, and instrumental to the transition of capability by small businesses. Over the last three years, the Air Force has received over 2,200 white paper submissions from vendors offering solutions to critical Air Force needs. We have awarded over 60 projects directly to small businesses and anticipate awarding another 25 by the end of this fiscal year.

Projects from the Fiscal Year 2011 Rapid Innovation Program are now maturing and showing great promise. For example, one project developed a handheld instrument for quality assurance of surface preparation processes used in manufacturing of the F-35 aircraft. Current F-35 aircraft manufacturing processes require manual testing of 30,000 nut plates on each plane to ensure correct bonding of materials. The current failure rate is averaging 1% or 300 nut plates. Each

failure requires individual re-preparation and re-bonding with supervisory oversight. The Rapid Innovation Program project handheld device will significantly reduce the failure rate of adhesively bonded nut plates. In turn, this will reduce rework and inspection costs, increase aircraft availability, assist Lockheed Martin in achieving its target production rate, and reduce repetitive injury claims from employees. Lockheed Martin has been very closely monitoring this technology and will be completing a return-on-investment review in the coming months following prototype evaluation.

The Air Force continues to collaborate with other Federal agencies and Air Force acquisition programs to streamline our SBIR and STTR processes. We are also collaborating with the Air Force's Small Business office (SAF/SB) to implement the provisions of the reauthorization and to assist in maximizing small business opportunities in government contracts while enhancing the impact and value of small businesses.

For example, to improve the effectiveness of SBIR investments, the Air Force Research Laboratory has started to strategically bundle, coordinate, and align Air Force SBIR topics against top Air Force priorities identified by Air Force Program Executive Officers (PEO). In the Fall of 2013, the Laboratory began a pilot effort with the Air Force Program Executive Officer for Space to focus the combined investments of approximately 45 SBIR Phase I awards and 15 Phase II SBIR awards on the identified, top priority challenge of transforming our military space-based PNT capabilities.

In conjunction with this strategic initiative, the Air Force is also energizing efforts to seek out and attract non-traditional participants, which are small businesses with skills, knowledge and abilities relevant to the bundled topics, in SBIR awards but who, for various reasons, do not routinely participate in the SBIR proposal process. This strategic concentration of small business innovation against top priorities will ultimately enhance the transitioning of small business

innovation, raise the visibility and importance of those investments, and take advantage of the nation's small business innovation. If proven successful, the Air Force will begin to institutionalize it as a model for organizing and aligning SBIR topics against other top priority issues.

One recent SBIR project developed innovative low profile and conformal antennas to allow air platforms , including small Remotely Piloted Aircraft (RPA), to operate more aerodynamically and ground vehicles to operate more covertly in areas where Improvised Explosive Devices (IEDs) are a threat. The wideband low profile antenna assembly for vehicle Counter Radio Controlled IED Electronic Warfare (CREW) systems operates efficiently from VHF to S-band, and at a height of less than 3 inches, greatly reduces visual signature. The wideband conformal antenna technologies developed for RPA systems operate from UHF through S-band and minimize the number of required antennas, significantly reducing weight and aerodynamic drag.

WORLD CLASS WORKFORCE

Maintaining our U.S. military's decisive technological edge requires an agile, capable workforce that leads cutting-edge research, explores emerging technology areas, and promotes innovation across government, industry and academia. Nurturing our current world class workforce and the next generations of science, technology, engineering, and mathematics (STEM) professionals is an Air Force, DoD and national concern. We must be able to recruit, retain and develop a capable STEM workforce in the face of worldwide competition for the same talent.

The Air Force continues to focus on developing technical experts and leaders who can provide the very best research and technical advice across the entire lifecycle of our systems, from acquisition, test, deployment and sustainment. After yielding success since 2011, the original *Bright Horizons, the Air Force STEM Workforce Strategic Roadmap*, is currently being updated with new goals and objectives to reflect the current environment. The Air Force has also developed

a soon-to-be-released *Engineering Enterprise Strategic Plan* aimed at recruiting, developing and retaining the scientist and engineer talent to meet the future need of the Air Force.

The increased Laboratory hiring and personnel management authorities and flexibilities provided by the Congress over the last several years have done much to improve our ability to attract the Nation's best talent. The Air Force is currently developing implementation plans for the authorities most recently provided in the Fiscal Year 2014 National Defense Authorization Act. The ability to manage Laboratory personnel levels according to budget will allow us to be more agile and targeted in hiring for new and emerging research areas. The Air Force Research Laboratory recruits up-and-coming, as well as seasoned, scientists and engineers, including continuing a vibrant relationship with Historically Black Colleges and Universities and Minority Serving Institutions (HBCU/MI), who conduct research projects, improve infrastructure, and intern with the Air Force Research Laboratory in support of the Air Force mission.

The Air Force also leverages the National Defense Education Program (NDEP) Science Mathematics and Research for Transformation (SMART) Program that supports U.S. undergraduate and graduate students pursuing degrees in 19 STEM disciplines. The Air Force provides advisors for the SMART scholars, summer internships, and post-graduation employment opportunities. The Air Force has sponsored 523 SMART scholars during the past eight years, and of the 315 scholars that have completed the program, 88% are still working for the Air Force, 9% are getting advanced degrees, and 3% have left due to various reasons including furlough and government funding uncertainty. The Air Force identified 110 Key Technology Areas essential for current and future support to the war fighter, which we used for selecting academic specialties for SMART scholars. SMART Scholars are an essential recruitment source of employees to enable key technology advances and future STEM leaders.

Sequestration and fiscal uncertainty in Fiscal Year 2013 caused the Air Force to significantly curtail travel expenses and severely limit conference attendance. It is essential for our scientists and engineers to be fully engaged within the national and international community so this curtailment disproportionately impacted the S&T community. We have worked with Air Force leadership to solve these issues and establish policies allowing greater flexibility for this mission imperative in 2014 and beyond. We can recover from the one year (2013) of non-participation in the greater S&T national and international community. However, severe travel restrictions over the long term could undermine the Air Force's ability retain top talent.

The Air Force has effectively used the authority provided by Section 219 of the Duncan Hunter National Defense Authorization Act not only to increase the rate of innovation and accelerate the development and fielding of needed military capabilities but also to grow and develop the workforce and provide premier Laboratory infrastructure. For example, the Information Directorate of the Air Force Research Laboratory located in Rome, New York used funding made available by Section 219 to develop curriculum at Clarkson University. The curriculum is aligned to the Information Directorate's command, control, communications, cyber and intelligence (C4I) technology mission and provides training and development programs to Laboratory personnel. To fully utilize the new Section 219 authorities from the Fiscal Year 2014 National Defense Authorization Act, the Laboratory is now developing a targeted infrastructure plan to provide its scientist and engineer workforce premier laboratory facilities in its locations nationwide. Recent success in the infrastructure area includes the opening of two state-of-the-art fuze laboratories at Eglin AFB, Florida, which are enabling enhanced research and development into hardened penetration and point burst fuzing.

CONCLUSION

The threats our Nation faces today and those forecast in the future leave the U.S. military with one imperative. We must maintain decisive technological advantage. We must take lessons from the last decade of conflict and creatively visualize the future strategic landscape. We must capitalize on the opportunities found within this space.

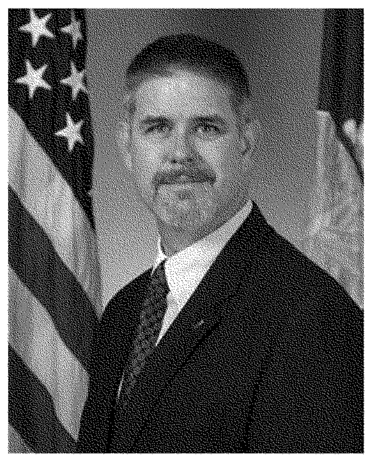
The focused and balanced investments of the Air Force Fiscal Year 2015 S&T Program are hedges against the unpredictable future and provide pathways to this flexible, precise and lethal force at a relatively low cost in in relation to the return on investment. We recognize that fiscal challenges will not disappear tomorrow, and that is why we have continued to improve our processes to make better investment decisions and efficiently deliver capability to our warfighters.

Chairman Thornberry, Ranking Member Langevin, Members of the Subcommittee and Staff, thank you again for the opportunity to testify today and thank you for your continuing support of the Air Force S&T Program.

BIOGRAPHY

UNITED STATES AIR FORCE

DR. DAVID E. WALKER



Dr. David E. Walker, a member of the Senior Executive Service, is Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering, Office of the Assistant Secretary of the Air Force for Acquisition, Washington, D.C.

Dr. Walker is responsible for preparing policy, guidance, and advocacy for the Air Force's annual $2 billion science and technology program. He provides annual testimony to Congress, technical advice and counsel to the Air Force Acquisition Executive, and the Air Force's science and technology recommendations to the Office of the Secretary of Defense. In addition, Dr. Walker is responsible for overseeing a broad range of engineering and technical management policy spanning systems engineering; environmental safety and occupational health; industrial preparedness; and functional management of more than 14,000 military and civilian scientists and engineers.

Dr. Walker retired from an active-duty Air Force career as a colonel in 2006. As a master navigator, he has more than 2,700 hours in 65 different types of aircraft including the RF-4C and the F-15E. He served in a variety of assignments in operations, developmental test and evaluation, science and technology and the Air Staff.

Prior to his current position, Dr. Walker served as Associate Deputy Assistant Secretary of the Air Force (Acquisition Integration), Washington, DC.

EDUCATION
1979 Bachelor of Science degree in aerospace engineering, University of Texas at Austin
1980 Master of Science degree in aerospace engineering, University of Texas at Austin
1984 Squadron Officer School, Maxwell Air Force Base, Ala.
1991 Air Command and Staff College, Maxwell AFB, Ala.
1994 Doctor of Philosophy degree in Aeronautical Engineering, Air Force Institute of Technology, Wright-Patterson AFB, Ohio
1997 Air War College, Maxwell AFB, Ala.
1999 Advanced Program Manager Course, Defense Systems Management College, Fort Belvoir, Va.
2009 APEX Senior Executive Orientation Program, Washington, D.C.
2010 Air Force Enterprise Leadership Seminar, Darden School of Business, University of Virginia, Charlottesville
2011 CAPSTONE, National Defense University, Washington, DC
2012 Senior Managers in Government, Harvard Kennedy School, Cambridge, Mass.

CAREER CHRONOLOGY

1. February 1980 - October 1980, Student, undergraduate navigator training and Tactical Navigation Course, Mather AFB, Calif.
2. October 1980 - June 1981, Student, RF-4C Replacement Training Unit, 33rd Tactical Reconnaissance Training Squadron, Shaw AFB, S.C.
3. June 1981 - May 1984, RF-4C Weapon Systems Officer, 38th Tactical Reconnaissance Squadron, Zweibrucken Air Base, West Germany
4. June 1984 - July 1984, Student, Squadron Officer School, Maxwell AFB, Ala.
5. August 1984 - June 1985, Instructor Weapon Systems Officer, 16th Tactical Reconnaissance Squadron, Shaw AFB, S.C.
6. June 1985 - June 1986, Student, Air Force Test Pilot School, Edwards AFB, Calif.
7. June 1986 - January 1987, Experimental Test Navigator, 6512th Test Squadron, Edwards AFB, Calif.
8. February 1987 - November 1988, Experimental Test Weapon Systems Officer, F-15 Combined Test Force, Edwards AFB, Calif.
9. November 1987 - July 1990, Executive Officer to the Commander, Air Force Flight Test Center, Edwards AFB, Calif.
10. August 1990 - June 1991, Student, Air Command and Staff College, Maxwell AFB, Ala.
11. June 1991 - June 1994, Doctoral Student, Air Force Institute of Technology, Wright-Patterson AFB, Ohio
12. July 1994 - May 1995, Chief, Instructor Training, Curriculum Development, USAF Test Pilot School, Edwards AFB, Calif.
13. May 1995 - July 1996, Deputy Commandant, Air Force Test Pilot School, Edwards AFB, Calif.
14. July 1996 - June 1997, Student, Air War College, Maxwell AFB, Ala.
15. July 1997 - June 1998, Deputy Chief, Common Systems Division, Directorate of Global Power Programs, Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
16. June 1998 - August 1999, Chief, Agile Combat Support Division, Directorate of Global Power Programs, Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
17. August 1999 - June 2001, Director, Air Vehicles Directorate, Air Force Research Laboratory, Wright-Patterson AFB, Ohio
18. June 2001 - July 2003, Commander, 412th Operations Group, Edwards AFB, Calif.
19. July 2003 - July 2006, Vice Commander, Air Force Research Laboratory, Wright-Patterson AFB, Ohio
20. July 2006 - September 2008, Director, Material and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson AFB, Ohio
21. September 2008 - May 2011, Associate Director of Programs, Deputy Chief of Staff for Strategic Plans and Programs, Headquarters U.S. Air Force, Washington, D.C.
22. May 2011 - August 2012, Associate Deputy Assistant Secretary of the Air Force (Acquisition Integration), Office of the Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
23. August 2012 - present, Deputy Assistant Secretary of the Air Force (Science, Technology and Engineering), Office of the Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.

AWARDS AND HONORS

Meritorious Executive Presidential Rank Award
Associate Fellow, American Institute of Aeronautics and Astronautics
Legion of Merit with two oak leaf clusters
Meritorious Service Medal with two oak leaf clusters
Air Medal
Air Force Commendation Medal
Air Force Achievement Medal
Distinguished graduate, ATC Commander's Cup, and Ira Husek Flying Trophy, Undergraduate Navigator Training
Top Gun, Tactical Navigation Course
Distinguished Graduate, RF-4C RTU
Distinguished Graduate and Outstanding Contributor, Squadron Officer School
Distinguished Graduate and Raymond L. Jones Award, USAF Test Pilot School
Distinguished Graduate, Air Command and Staff College

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Statement by

Dr. Arati Prabhakar

Director
Defense Advanced Research Projects Agency

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United States House of Representatives

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NOT FOR PUBLICATION UNTIL RELEASED BY THE SUBCOMMITTEE

Chairman Thornberry, Ranking Member Langevin and Members of the Subcommittee, thank you for the opportunity to testify before you today. I am Arati Prabhakar, Director of the Defense Advanced Research Projects Agency, DARPA. It is a pleasure to be here with my colleagues across the Department of Defense (DoD) Science and Technology (S&T) community. Our organizations work together every day to advance our Nation's defense technologies. DARPA plays a particular role in this community, and in the broader U.S. technology ecosystem. That role is to anticipate, create, and demonstrate breakthrough technologies that are outside and beyond conventional approaches – technologies that hold the potential for extraordinary advances in national security capability. This mission and our current work and plans are the focus of my testimony today.

DARPA's Mission and the Diverse Threats Facing our Nation

In the fall of 1957, a polished metal sphere, 23 inches in diameter and launched from Soviet soil, began its orbit around the Earth, passing over American skies approximately every 96 minutes and initiating the space age, a space race, and a new era in the long struggle to maintain American military and technological superiority. Starting DARPA was one of the pivotal choices our Nation made in the wake of Sputnik. America today enjoys a hard-earned, privileged position, with tremendous military might, economic strength, and social and political freedom. Yet, as this Subcommittee knows well, risk is ever evolving in our complex and dynamic world. Regional instability, shifting military and economic positions, demographic and natural resource trends – these forces drive constant change in our national security environment. Today and in the years ahead, our potential adversaries will still include nation states, but also smaller, less well defined bad actors and an increasingly networked terror threat. National security challenges will continue to range from the acute to the chronic. This is the threat environment that shapes our technology investments today at DARPA.

Adding to the security challenges we face is the fact that technology and its accessibility have changed so significantly. Startlingly powerful technologies – semiconductors, information systems, and nuclear and biological technologies among them – are now globally available to a much wider swath of society, for good and for evil. And while the cost of some technologies has dropped precipitously, other technology and non-technology related costs have risen steeply, leading DoD to difficult choices about our operational capabilities. That means our assumptions about the cost of military systems must change. I discussed these factors in some depth in last year's testimony, and they, too, continue to shape our investments at DARPA.

DARPA was designed and built for just this kind of shifting, challenging threat environment. Through more than 5 decades of tumultuous geopolitical and technological change, we have delivered outsized impact by focusing on our mission of breakthrough technologies for national security. We imagine groundbreaking new technology advances with the potential for defense applications. We bring the best of those ideas to fruition by providing the right mix of research support, intellectual freedom, and responsible oversight to outstanding performers in industry, academia, and other government organizations. And we facilitate the transition and operationalization of these new, paradigm-shifting capabilities.

Harnessing Complexity to Create Exceptional New Capabilities: DARPA's Programs

Like most truly great problems that confront us, today's diverse threats can either be viewed as an imposing barrier or as an opportunity to overcome a difficult challenge. Either way, I believe our national security will depend upon how we deal with complexity. DARPA chooses to tackle complexity by harnessing it, and our programs reflect that approach of playing offense. We do that with game-changing new capabilities and with layered, adaptable, multi-technology systems. We do that by catalyzing major new national technology advances and by rapidly exploiting commercially available technologies. And at a time when systems cost is the difference between building operational capability or just building PowerPoint, we do that by striving to invert the cost equation for our military.

DARPA has made important strides forward in delivering key breakthrough technologies since I last testified before this Subcommittee. In discussing how we are tackling various aspects of technological complexity, I will update you on several new programs that we have launched, results we have achieved, and transitions that have been accomplished or are in process.

Rethinking Complex Military Systems

Much of DARPA's work rethinks complex military systems, recasting today's approach with the intention of achieving far greater capabilities at lower cost. Today, our military relies upon the meshing of electronic, optical, software, and mechanical components to create satellites and the vehicles, aircraft, and ships that carry our Warfighters into battle. We also depend upon this integration of components in designing and producing the weapons these men and women must be prepared to use. That is not new. But today, these technology components are becoming ever more complex. Consider: radar systems have thousands of antenna elements, platforms run millions of lines of code, and integrated circuits are made of billions of transistors. These many components are also now interdependent and interacting to an unprecedented degree. And, of course, these platforms and mission systems must operate in an environment that will be increasingly contested by others with access to ever-improving global technologies. All these factors contribute to the high cost, long development times, and inflexibility of today's most advanced systems. This demands that we rethink – sometimes in fundamental ways – how we approach the next generation of defense systems.

Let me give you a few examples of how DARPA is tackling this challenge from our portfolio of programs.

Robust Space

In times of conflict, our Nation's leaders count on our military to wage precise, overpowering war. This type of highly effective warfighting is critically dependent on space – for imaging and sensing, for communications, for navigation, even for keeping time. As never before, we require ready access to space and strategic control over our assets in space. But while space is becoming increasingly crowded and contested, DoD's ability to access and operate in space has become less nimble and more expensive over many years. DARPA has several programs underway to change that equation.

Rapid Launch: Experimental Space Plane (XS-1) and Airborne Launch Assisted Space Access (ALASA)

Imagine a world in which getting a satellite into orbit can be as quick and reliable as an aircraft takeoff. Our new Experimental Spaceplane is designed to take a 3,000 to 5,000-pound payload into orbit using an expendable upper stage, all for under $5 million; that is one-tenth the cost of a comparable launch today. Our ALASA program focuses on 100-pound payloads for less than $1 million. Even more striking is our goal of providing satellite launches for these payloads with just 24 hours' notice.

Avoiding Collisions in Space: Space Surveillance Telescope (SST)

In space, one major challenge is simply a lack of knowledge of what is around you. With satellite traffic and the risk of space collisions growing, space domain awareness is a top priority. DARPA's SST enables much faster discovery and tracking of previously unseen, hard-to-find objects in geosynchronous orbits. We expect it to be ready for operations within 2 years in Australia as a result of a memorandum of understanding signed last November by Secretary of Defense Hagel with his counterpart. Once operational on the Northwest Cape of Australia, SST will provide detection and tracking of satellites and space debris at and near geosynchronous orbits within the Asia-Pacific region, information U.S. space operators can use to better protect critical U.S. and Allied space-based capabilities.

Lowering the Risk and Cost for Satellites

Communications satellites in geosynchronous orbit, approximately 36,000 kilometers above the earth, provide vital communication capabilities to Warfighters and others. Today, when a satellite fails, we usually face the expensive prospect of having to launch a brand new replacement. Our Phoenix program strives to develop and demonstrate technology to robotically service, maintain, and construct satellites in the harsh environment of geosynchronous orbit. Phoenix is also exploring a paradigm change to satellite design that would enable ground and on-orbit assemble-able platforms to potentially lower the cost of next-generation space systems by a factor of 10 compared to what is possible today.

Winning in Contested Environments

Space is not the only environment that is growing more crowded and dangerous. We must always anticipate an actively contested environment as we look ahead to potential challenges from future adversaries. Today, we are dependent on centralized command and control, and the fragile lines of communications linking tactical assets to decision makers. While DARPA has multiple programs addressing these challenges for the air, ground, and sea, a common thread is the development of technologies to shift and distribute capability at the forward edge of the battle and to adapt quickly to a changing technology landscape.

Long-Range Anti-Ship Missile (LRASM)

Today's anti-ship missiles face challenges penetrating sophisticated air defense systems from long range. As a result, Warfighters may require multiple missile launches and overhead targeting assets to engage specific enemy warships from beyond the reach of counter-fire systems. In important progress to overcome these challenges, the DARPA-Navy LRASM program has had a series of successful flight tests on a precision-guided anti-ship standoff missile. That will reduce dependence on intelligence, surveillance, and reconnaissance platforms, network links, and Global Positioning System (GPS) navigation in electronic warfare environments. DARPA is collaborating with the Navy via a new joint program office, helping to move this leap-ahead capability to deployment very quickly.

Distributed Battle Management (DBM) and Communications in Contested Environments (C2E)

Under our Air Dominance Initiative, DARPA, the Air Force, and the Navy together have been exploring systems-of-systems concepts in which networks of manned and unmanned platforms, weapons, sensors, and electronic warfare systems interact to succeed in a contested battlespace. These approaches could offer flexible and powerful options to the Warfighter, but the complexity introduced by the increase in the number of employment alternatives – particularly in a dynamic situation – creates a battle management challenge. Further complicating matters, in future conflicts U.S. forces may face degradation or denial of critical communications capabilities essential for coordination and shared situational understanding.

We recently launched two programs that address these challenges. The Distributed Battle Management (DBM) program seeks to develop control algorithms and demonstrate robust decision-aid software for air battle management at the tactical edge. Our new Communications in Contested Environments (C2E) program is, at the same time, exploring the use of reference architectures to enable robust, scalable, and rapidly evolvable airborne communications networks.

<u>Dominating the Electromagnetic Spectrum</u>

The challenge of the threat environment extends to the airwaves as well, a reality that also is beginning to affect commercial and civil activity as demand continues to grow for access to the electromagnetic spectrum. The United States and our Allies learned an important lesson in World War II, when we became the first to control and take advantage of one small part of the spectrum – the range occupied by radar. By many assessments, Allied dominance in radar technology was pivotal to our winning that crucial war. Today we can say that the next war may be won by the nation that controls the electromagnetic spectrum over the full range of wavelengths – a degree of control that can ensure dominance in communications and in the important linked domains of timing, location, and navigation. It also can ensure dominance in seeing what our adversaries are doing, and in controlling what they see of us – both our capacity to hide things from their sensors and our capacity to make "visible" an array of things that are not really there.

Spectrum Challenge

One approach to dominating the spectrum is simply to be more nimble, both in sensing and using whatever portions of the spectrum are available. Radios, for example, lack agility, despite the fact that they are used for the most mundane to the most critical of communications, from garage

door openers to first responders to military operations. Wireless devices often inadvertently interfere with and disrupt radio communications, and, in battlefield environments, adversaries may intentionally jam friendly communications. To stimulate the development of radio techniques that can overcome these impediments, DARPA launched its Spectrum Challenge, a national competition to develop advanced radio technology capable of communicating in congested and contested electromagnetic environments without direct coordination or spectrum preplanning. We expect to see a massive increase in innovation when the teams return for the final part of the Challenge with promising results for future applications.

Moving to New Frequency Domains: Terahertz Electronics (THz)

Another way to control the spectrum is to move to new frequency domains, where hardware limitations currently prevent us from operating effectively. The submillimeter wave, or terahertz, part of the electromagnetic spectrum falls between the frequencies of 0.3 and 3 terahertz, between microwaves and infrared light. Unlocking this band's potential may benefit military applications such as high-data-rate communications, improved radar, and new methods of sensing. But access to these applications has been limited due to physics and our limited understanding.

Researchers under DARPA's Terahertz Electronics (THz) program have designed and demonstrated a 0.85 terahertz power amplifier using a micromachined vacuum tube; we believe it to be a world first. The vacuum tube power amplifier is one achievement of the broader THz program, which seeks to develop a variety of breakthrough component and integration technologies necessary to one day build complex terahertz circuits for communications and sensing.

Many more DARPA programs also rethink complex military systems. These include efforts to use the undersea environment to observe and access regions around the world, to rapidly bring advances in commercial technology to the battlefield; to develop hypersonic technologies for advanced speed, reach, and range; and to create new distributed architectures for the contested environments of the future.

Information at Scale

Let's consider a different aspect of complexity. As the information revolution continues, the sheer scale and variety of data seems immensely, and perhaps overwhelmingly, complex – but this challenge also presents major opportunities.

Insight to Enhance Analysts' Capabilities and Performance

Military intelligence analysts face the monumental and escalating task of analyzing massive volumes of complex data from multiple, diverse sources such as physical sensors, human contacts, and contextual databases. DARPA's Insight program addresses the need for new tools and automation to enhance analyst capabilities and performance. The program seeks to enable analysts to make sense of the huge volumes of intelligence-rich information available to them from existing sensors and data sources. Automated behavioral learning and prediction algorithms help analysts discover and identify potential threats, as well as make and confirm hypotheses about those threats' potential behavior. The goal is a comprehensive operating picture in which expedient delivery of fused actionable intelligence improves support of time-sensitive operations

on the battlefield. We are working closely with the Army and the Air Force to transition operational capabilities to programs of record.

MEMEX: A Different Approach to Search

Despite the vast amounts of data available, today's web searches use a centralized, one-size-fits-all approach that searches the Internet with the same set of tools for all queries. While that model has been wildly successful commercially, it does not work well for many government use cases. Current search practices miss information in the deep web – the parts of the web not indexed by standard commercial search engines – and ignore shared content across pages.

To help overcome these challenges, DARPA launched the Memory and Exploration of the Internet for Defense (MEMEX) program. This ambitious effort seeks to develop domain-specific search technologies and revolutionize the discovery, organization and presentation of the types of search results needed for national security concerns. MEMEX's initial focus will be human trafficking, which is a factor in many types of military, law enforcement and intelligence investigations and has a significant web presence to attract customers.

Mining and Understanding Software Enclaves (MUSE)

Information at scale includes not just data, but software code as well. Within the last few years, there has been a tremendous explosion in the number of open source projects and the size of codebases these projects contain. Software repositories today are estimated to contain more than 100 billion lines of code, and the number continues to grow. Open source software is widely used in mission-critical DoD systems as well as in the commercial world. DARPA's new Mining and Understanding Software Enclaves (MUSE) program aims to harness the scale and complexity of this array of software to instigate a fundamental shift in the way we conceive, design, implement, and maintain software. If successful, MUSE could lead to a new programming methodology, leading to automated mechanisms for improving resilience, reducing vulnerabilities, and simplifying the construction of software systems.

High-Assurance Cyber Military Systems (HACMS)

Embedded systems form a pervasive network that underlies much of modern technological society. Such systems range from large supervisory control and data acquisition (SCADA) systems that manage physical infrastructure to medical devices such as pacemakers and insulin pumps, to computer peripherals such as printers and routers, to communication devices such as cell phones and radios, to vehicles such as automobiles and airplanes. These devices have been networked for a variety of reasons, including the ability to conveniently access diagnostic information, perform software updates, provide innovative features, lower costs, and improve ease of use. But researchers and hackers have shown that these kinds of networked embedded systems are vulnerable to remote attack, and such attacks can cause physical damage while hiding the effects from monitors. DARPA launched the High-Assurance Cyber Military Systems (HACMS) program to create technology to construct high-assurance cyberphysical systems. Achieving this goal requires a fundamentally different approach from what the software community has taken to date. If successful, HACMS will produce a set of publicly available tools integrated into a high-assurance software workbench, which will be widely distributed for use in both the commercial and defense software sectors. For the defense sector, HACMS will

enable high-assurance military systems ranging from unmanned vehicles to weapons systems, satellites, and command and control devices. In an early demonstration of the program, we are running first-of-its-kind provably correct software on a commercially available automobile.

These programs are examples from DARPA's broader portfolio in cyber and information at scale. Other efforts are developing new technologies to enable distributed computer systems to work through attacks; permit trustworthy Internet communications in untrusted environments; automate the discovery, identification, and characterization of new malware; provide DoD with military cyber capabilities; and automatically process text information to discover meanings and connections that might otherwise not be readily apparent to analysts.

Biology as Technology

A third area of complexity of growing interest and importance to DARPA – and among the most promising for future major capabilities – is the idea of biology as technology. Biology is nature's ultimate innovator, and any agency that hangs its hat on innovation would be foolish not to look to this master of networked complexity for inspiration and solutions.

Living Foundries

Synthetic biology – a hybrid discipline of biology and engineering – has already proven itself capable of using customized bacteria to produce medicines, and now it is heading toward even more interesting applications as we harness it to create entirely new chemistries. Our Living Foundries program seeks to develop the next-generation tools and technologies for engineering biological systems, compressing the biological design-build-test cycle in both time and cost. For example, the program has demonstrated the ability to generate a suite of novel bioproducts in weeks rather than years. The program is also producing new classes of materials with novel properties that can enable a new generation of mechanical, optical, and electrical products.

Rapid Threat Assessment (RTA)

Even as we develop new materials and tools for engineering biological systems, we understand that we must also be prepared to react quickly to how our adversaries may seek to use similar capabilities. This concern is not new: novel chemical and biological weapons have historically been mass-produced within a year of discovery. Using current methods and technologies, researchers would require decades of study to gain a cellular-level understanding of how new threat agents affect humans. This gap between threat emergence, mechanistic understanding and potential treatment leaves U.S. forces and populations here and around the world vulnerable.

DARPA launched the Rapid Threat Assessment (RTA) program with an aggressive goal: develop methods and technologies that can, within 30 days of exposure to a human cell, map the complete molecular mechanism through which a threat agent alters cellular processes. This would give researchers the framework with which to develop medical countermeasures and mitigate threats. If successful, RTA could shift the cost-benefit trade space of using chemical or biological weapons against U.S. forces and could also apply to drug development to combat emerging diseases.

Brain Function Research

In an era when harnessing complexity will be the *sine qua non* of success, it should not be surprising that DARPA has a particular interest in tackling the brain. DARPA's interest starts with our desire to protect and assist our Warfighters, whether it means preventing or treating traumatic brain injury, easing the effects of post-traumatic stress disorder, or learning to operate sophisticated prosthetic limbs with thoughts alone, as is now increasingly possible with our new and exciting technologies. These advances also open the door to a much deeper understanding of how humans interact with the world around them – new insights that may fuel the next revolution in how we work with complex technologies and systems. Over the past year, we launched several new brain function-related programs that are now getting underway. These efforts are part of the President's initiative in brain research. Recently, we have made unprecedented advances in developing advanced prosthetic arm systems and methods to restore near-natural movement and control.

DARPA's biology-related investments also include diagnostics and novel prophylaxes to outpace the spread of infectious disease and new methods to accelerate the testing of critical therapeutics.

New Frontiers

Consistent with our mission to prevent technological surprise by creating it, DARPA continues to invest across a wide range of fields where we see promising research that could lead to powerful technology capability. These investments are the seeds of what my successors, perhaps 5, 10, or 15 years from now, will be describing to you as technology revolutions.

I described earlier our work in developing new algorithms, software, and architectures that allow us to better mesh our electronic, optical and mechanical components together. What about those components themselves? We are pushing the frontiers of physics to make them dramatically smaller, or more capable, or both.

iPhod, COUGAR, and ORCHID

Consider the many ways we are developing to harness light, which will directly affect the size, weight, cost, and performance of military components ranging from small navigation sensors to phased array radars and communication antennas. One recently concluded program (iPhod) successfully miniaturized tools for creating delays in light transmission, while another (COUGAR) demonstrated unique designs in hollow core fibers, which guide light within a device much more efficiently than conventional optical fibers. Yet another (ORCHID) successfully demonstrated the "squeezing" of light, a concept in quantum optics that can ultimately lead to dramatic performance gains in microsystems. These programs challenge the assumption that highly-specialized, high-precision systems must be large and expensive.

Miniaturization with National Security Implications

Other advances in miniaturization include a recent demonstration by DARPA-funded researchers of the world's smallest vacuum pumps. This breakthrough technology may create new national security applications for electronics and sensors that require a vacuum: highly sensitive gas analyzers that can detect chemical or biological attack, for instance, or extremely accurate laser-cooled chip-scale atomic clocks and microscale vacuum tubes. As part of another program

(QuASAR), one which seeks to exploit the extreme precision and control of atomic physics for new sensor technology, researchers have developed methods for measuring magnetic fields at scales smaller than the size of a single cell. Applications include critical advances in position, timing, and navigation – all critical to military situational awareness and operations.

Ground Robotics

Some advances seem at our doorstep – thanks to science fiction and the amazing special effects of creative individuals and teams who lead our entertainment industry. At the DARPA Robotics Challenge trials a few months ago, we drove robotics technology forward by engaging teams of creative specialists at companies, universities, and other government agencies. These world-leading experts were charged with advancing the capabilities of robots to perform basic skills that would be required in carrying out humanitarian and disaster relief missions. The Robotics Challenge – which is still underway – is showing how robotics capabilities can advance. It is also demonstrating just how far these kinds of robots are from serious battlefield application. That, too, is part of DARPA's mission: push the research frontiers of what is possible and inform our military decision makers where those limits are and the prospects for the future.

Algorithms Opening New Horizons

Research in mathematical algorithms is also creating important new technological opportunities. Clustering algorithms can detect common activity patterns across a vast data set. A combination of vector mathematics, time integration, and power law distributions enables the analysis of ensemble behaviors – patterns that only become visible when correlated across large numbers of points. Time series analysis can find previously unknown outliers in a data set for anomaly detection. Our programs apply these mathematical techniques to immense data sets with hundreds of millions or even many billions of elements. Individually or in combination, these new algorithmic approaches enable rapid analysis of data volumes that finally begins to scale with the complexity of the national security challenges that we face today.

People, Process, and Budgets

I have cited several examples of DARPA technologies that made significant progress in the last year. There are many more in that same category. Additional examples of successes in the making are attached to my testimony.

What does it take for DARPA to do these transformative things? It takes the right people, process, and funding. And the support of this Subcommittee has been essential for each of these.

People

For DARPA to remain as creative and effective as it has been through its history, first and foremost we depend upon stellar program managers. They come to DARPA with inspirations about achieving breakthroughs in technologies that stand conventional wisdom on its head, mindful of the rare opportunity to bring about rock-the-boat changes that will contribute to our national security. We keep these program managers onboard typically for 3 to 5 years; that helps to infuse new people with fresh views into the Agency continuously. That means we need to quickly identify and bring in experts who frequently are widely sought after by the private sector, academia, and other government agencies.

The 1101 hiring authority Congress has provided to DARPA is key to our continuing success and makes a very concrete, positive difference in our ability to recruit incomparable program managers. I thank the Subcommittee for its continued support and extension of this special authority over a lengthy period.

Processes

Likewise, the authority to conduct Challenges is a very effective part of our toolbox of innovative management approaches. It complements the variety of other means we have for working with the technical community, including more traditional awards to performers and collaborative undertakings. Our Challenges reach a broad range of performers by offering prizes to those who accomplish previously unattainable goals. They have proven to be an extraordinarily effective way to tap the creative ideas of an ever-wider community to help DARPA push the frontiers of technology forward. Last year, Congress extended the Challenge authority until September 30, 2018. Thank you for continuing this important authority. In FY 2014 alone, we are in the midst of the DARPA Robotics Challenge, the Cyber Grand Challenge, and the Spectrum Challenge.

Budget

The President's FY 2015 budget request for DARPA is $2.915 billion. This compares with $2.779 billion appropriated for FY 2014, an increase of $136 million. Before describing our FY 2015 plan, let me put this number in context.

From FY 2009 to FY 2013, DARPA's budget declined through a series of small reductions followed by the 8 percent across-the-board sequestration cut in FY 2013. The total reduction to DARPA's budget from FY 2009 to FY 2013 was 20 percent in real terms.

This pernicious trend turned around last year. I thank this Subcommittee, and Congress more broadly, for your support in helping us to begin to address this issue in FY 2014 by restoring an initial $199 million. The President's FY 2015 request continues restoration, almost returning the Agency's budget to its pre-sequestration level in real terms.

Let me outline what these budget changes mean in terms of our ability to execute DARPA's vital mission. As budgets eroded over the last few years, one effect was a reduction in our major demonstration programs. In some cases, we have been unable to advance our work to the point of actually demonstrating that a totally new approach is workable. In other cases, we had to rely on a single approach to solving a particularly challenging problem because we could fund only one performing organization. That is especially problematic since we are trying to do something that has never been achieved before. Reduced funds also meant fewer early-stage investments to explore new research frontiers. Sequestration further affected our programs, with many being delayed or reduced.

In the current fiscal year, the partial restoration of funds is making a real difference in DARPA's ability to attack the thorny problems the nation faces in today's military and national security environment. As a projects agency, DARPA is always beginning new programs as old ones end. But the new efforts in FY 2014 are stronger because of the healthier budget level. In some areas, we are now able to plan for the real-world prototyping and field testing needed for new concepts to be fully evaluated. And our new programs include the important exploratory projects that will

expand future national security opportunities. The FY 2015 request before you today will allow us to continue to restore and strengthen our portfolio of investments. With this funding level, we will be on the right track.

Let me close by saying that I am mindful of the challenges that our Nation faces and the increasingly difficult environment in which we work, including severe constraints on resources. But I also am excited about what lies ahead and confident that – with your support for the President's FY 2015 budget request – DARPA will continue to make a real and outsized difference in redefining the national security landscape and our Nation's security.

Again, thank you for your support – past, present, and future. I look forward to working with you, and will be pleased to respond to your questions.

-end-

Addendum

DARPA Transitions

Many technologies from earlier DARPA investments are now moving forward with a wide variety of our partners and customers. These summaries provide snapshots of progress for some programs from recent years.

Leap Ahead in Surface Warfare Capabilities by Reducing Dependence on ISR Platforms, Network Links, and GPS: Long Range Anti-Ship Missile (LRASM)

Technology Description and Program Goal

- Our current anti-ship missiles must penetrate sophisticated enemy air defense systems from long range. As a result, Warfighters may require multiple missile launches and overhead targeting assets to engage specific enemy warships from beyond the reach of counter-fire systems. To overcome these challenges, the DARPA-Navy Long Range Anti-Ship Missile (LRASM) program is investing in advanced technologies to provide a leap ahead in U.S. surface warfare capability.
- LRASM aims to reduce dependence on intelligence, surveillance and reconnaissance (ISR) platforms, network links, and GPS navigation in electronic warfare environments. Autonomous guidance algorithms should allow LRASM to use less-precise target cueing data to pinpoint specific targets in the contested domain. The program also focuses on innovative terminal survivability approaches and precision lethality in the face of advanced countermeasures.
- LRASM began in 2009. Now in its final DARPA phase, this program leverages the state-of-the-art Joint Air to Surface Standoff Missile Extended Range (JASSM-ER) airframe and incorporates additional sensors and systems to achieve a stealthy and survivable subsonic cruise missile.
- ***In 2013, DARPA conducted two flight demonstrations, each with resounding success.*** The LRASM was dropped from an Air Force B-1, successfully separated from the aircraft, navigated through a series of preplanned waypoints, and then transitioned to an autonomous mode while seeking the target it had been instructed to attack. ***The missile detected, identified, and tracked the mobile ship target at extended range; transitioned to guidance on the terminal sensor; and impacted the target*** with a miss distance well within acceptable error probabilities. Other flight achievements include weapon data link updates, transmission of weapon in-flight tracks, and increased flight range.

Transition Plan and Status

- The program is on track to deliver an advanced prototype weapon to the Navy and Air Force with capability for challenging future operational environments, while being sufficiently mature to transition rapidly to an acquisition program to address near-term operational challenges.
- DARPA is engaged with the U.S. Navy NAVAIR's Program Executive Office for Unmanned Aviation and Strike Weapons (PEO U&W) to provide an innovative management approach for rapid acquisition of LRASM for Air Force and Navy air launch platforms to meet offensive anti-surface warfare missions. This approach leverages DARPA investment, program security, contracts, and infrastructure. Ultimately, it will leverage DARPA's technology development and risk reduction efforts to expeditiously field LRASM. In FY 2014, DARPA and Navy efforts

include continued technology development, integration risk reduction, and pre-Milestone B activities.

- ***DARPA has transitioned the technology to a new DARPA/Navy/Air Force co-staffed office chartered by USD(AT&L) to rapidly deploy this dramatically enhanced new capability.***

Reducing Drag and Fuel Usage: Formation Flight for Aerodynamic Benefit

Technology Description and Program Goal

- With the Air Force consuming more than 2.5 billion gallons of aviation fuel in 2010, DARPA launched the Formation Flight for Aerodynamic Benefit program to seek creative ways to reduce drag and fuel usage in the C-17 fleet.
- C-17s are the largest single user of aviation fuel, consuming 650 million gallons (26 percent) in 2010. DARPA's goal was to achieve a 10 percent reduction in fuel flow.
- The approach taken was motivated by large flocks of migratory birds that fly in a "V" formation.
- All aircraft produce wingtip vortices when flying, which are a drag byproduct of producing aerodynamic lift. After analyzing C-17 wingtip vortices, DARPA predicted optimum formation positions.
- The DARPA program created new software that innovatively enabled precise autopilot and auto-throttle formation flight operations with existing C-17 hardware.
- DARPA simulation, modeling, and lab testing projected success in reaching the target reduction in fuel flow using this software modification.

Transition Plan and Status

- DARPA transitioned the software to the Air Force Research Laboratory (AFRL) in July 2012 as the Surfing Aircraft Vortices for Energy ($AVE) program.
- AFRL conducted 30 hours of flight testing in C-17 formation flight, including 12 hours on operational flight routes over the Pacific in 2013.
- ***That testing validated a 10 percent fuel flow reduction with the DARPA software modification. Moreover, the changes were safe, aircrew friendly, and aircraft friendly – and made business sense.***
- The Applied Technology Council approved funding for an Advanced Technology Demonstration (ATD) of the DARPA C-17 software-only modification. The ATD will enable the Air Mobility Command to develop CONOPS for rapid fielding this DARPA energy efficiency advancement.
- ***AFRL is examining use of this technology to obtain fuel savings on C-130s and other DoD platforms.***
- Commercial carriers, the Federal Aviation Administration, and the National Aeronautics and Space Administration (NASA) expressed interest in civilian applications of this DARPA technology.
- This DARPA program success reflects significant contributions from the Air Mobility Command, AFRL, 412th Test Wing, Air Force Life Cycle Management Center, Boeing Company, and NASA Neil A. Armstrong Flight Research Center.

New Approaches to Tackling DoD's Language Challenges: BOLT, RATS, and MADCAT

Technology Description & Program Goal

- DARPA has invested in solutions for DoD to recognize, classify, and help digest written and spoken foreign languages.
- Technology from the Broad Operational Language Translation (BOLT) program provides automated translation and linguistic analysis that can be applied to informal genres of text and speech as well as multilingual search capability and unrestricted multi-turn bilingual conversation.
- The Robust Automatic Transcription of Speech (RATS) program creates algorithms and software to perform the following tasks on potentially speech-containing signals received over channels that are extremely noisy and/or highly distorted: speech activity detection, language identification, speaker identification, and keyword spotting in foreign languages.
- The Multilingual Automatic Document Classification Analysis and Translation (MADCAT) program automatically converts foreign language text images into English transcripts, eliminating the need for linguists and analysts while automatically providing relevant, distilled actionable information to military command and personnel in a timely fashion.

BOLT Transition Plan and Status

- The Combating Terrorism Technical Support Office (CTTSO), under the Assistant Secretary of Defense for Special Operations/Low-Intensity Conflict, ***successfully transitioned to military users a tool for translation of and topic spotting and data exploitation in social media***. Initial implementation is with a military user with plans to extend use to multiple government, military, and academic media monitoring system users.

RATS Transition Plan and Status

- The Air Force has provided lab facilities to test RATS capability using operational data. ***Initial evaluations show RATS technology superior to any other system***, and plans are underway for integrating the speech activity detection portion of the RATS technology into systems that provide noisy speech signal processing capabilities. Other interested DoD elements are awaiting the results of operational field trials before pursuing acquisition.

MADCAT Transition Plan and Status

- MADCAT optical character recognition has been coupled with machine translation and deployed in 11 languages to enable English-speaking government and military personnel to read hardcopy foreign language documents. A project also is underway to further develop Korean optical character recognition and machine translation to support user requirements.
- MADCAT offline handwriting recognition system was delivered to a government user in 2011 and is in ***operational use. The CTTSO is supporting the MADCAT transition to various other DoD and intelligence community users.***

Achieving Dramatically Faster Mapping: High-Altitude LIDAR Operations Experiment (HALOE)

Technology Description and Program Goal

- Leveraging past DARPA developments in Light Detection and Ranging (LIDAR) systems, a sensor pod for rapid collect, wide area, long range, high-resolution 3D datasets was developed for the HALOE system. In 2010 and 2011, DARPA invested funds to harden the sensor system in preparation for a prolonged operational trial in Afghanistan.
- ***HALOE provided forces in Afghanistan with unprecedented access to high-resolution 3D data, and it collected orders of magnitude faster and from much longer ranges than conventional methods.*** At full operational capacity, HALOE could enable mapping of 50 percent of Afghanistan in 90 days. State-of-the-art deployed systems would have required 3 years to accomplish that task, and more conventional systems would have required 30 years.
- This increased performance is enabled by advances in shortwave infrared sensitive material properties that permitted photon-counting detector arrays so sensitive that it is now possible to make range measurements with fewer than 10 photons received, versus tens of thousands of photons. As is true with any camera, increased sensitivity means an image can be captured more quickly since the shutter has to be open for less time – and less light is required to capture an image. Less time and less power translate to higher collection rates at greater standoff. HALOE can collect data at a rate more than 10 times faster than state-of-the-art systems or 100 times faster than conventional systems.
- HALOE was one of several DARPA advances directly supporting the Warfighter that earned the agency the Joint Meritorious Unit Award from the Secretary of Defense late in 2012.

Transition Plan and Status

- The HALOE sensor pod was initially integrated onto a WB-57 aircraft and deployed to Afghanistan from November 2010 through August 2011 in a ***joint effort with the Army Geospatial Center (AGC)***. During this time, over 70,000 square kilometers of terrain data (about 10 percent of Afghanistan) were collected, reflecting the priorities of operational units.
- In March 2012, **with AGC funding**, the HALOE sensor pod was integrated onto a BD700 aircraft, a highly customized, longer-range flight platform.
- In July 2013 the HALOE system was deployed to the AFRICOM Area Of Responsibility (AOR). The system collected data in Africa during eight flight sorties through August.
- In September 2013, HALOE was transferred to Afghanistan in September 2013.
- ***HALOE performed exceedingly well in its several deployments in Afghanistan***, collecting more than 83 percent of all tasked regions with a cumulative mission area of greater than 74,000 square kilometers. The collected data have been in response to multiple RFIs in support of operational units. The HALOE system has transitioned out of theater, with the last sortie flown in December 2013.
- Plans call for a 6-month period in CONUS for maintenance and training followed by ***redeployment in June 2014*** for the remainder of FY 2014. Potential locations include AOR of USCENTCOM (not Afghanistan), USAFRICOM, and USPACOM.

Blast Monitoring Tool Also Will Improve Future Understanding of Injuries: Blast Gauge

Technology Description and Program Goal

- Blast Gauge is a low-cost, disposable, individually wearable sensor system that records the environment during an explosive event – for example, an attack from an improvised explosive

device (IED) or a rocket-propelled grenade (RPG), or the firing of a missile or rocket during training.

- ***The goal was to rapidly develop and field a system to quantify blast exposure, assist commanders in finding injured Service Members who would otherwise not report, and record data to understand blast injuries, including traumatic brain injury (TBI).***
- DARPA recognized that blast overpressure and linear acceleration must be recorded – and at multiple points on the body– to understand blast-related injuries and that the needed technology could be built completely out of common commercial components.
- The device was developed in just 11 months; Special Operations Forces (SOF) fielded Blast Gauge in Afghanistan in July 2011 and Rochester Institute of Technology researchers who developed the dosimeter quickly formed a small business to commercialize and manufacture the gauges.
- ***Costing less than $50 per device,*** the gauge includes a simple three-light system (red, yellow, green) to indicate condition and magnitude immediately following a blast. Service Members wear three gauges: on the back of the helmet, shoulder, and chest. This allows a blast to be captured regardless of its relative location.
- Information is transmitted to medical staff and researchers; doctors and medics report that the lights are a valuable feature for augmenting triage following a blast.
- DARPA also developed a system to capture the data, contributing to better understanding of the effects of blasts on the brain.

<u>Transition Plan and Status</u>

- DARPA completed development with release of the latest generation gauge in June 2013. It can be purchased directly from the manufacturer or from Defense Logistics Agency stock.
- DARPA initially provided field support to train Soldiers on the gauges and to distribute gauges and collect exposure data. More than 150,000 gauges (50,000 sets) have been distributed to all Services.
- ***As a result of the DARPA-funded field trials, Blast Gauge technology has been adopted by SOF and the Army:***
    - The Combined Joint Special Operations Task Force Afghanistan (CJSOTF-A) mandated that all special operators in its task forces use blast gauges. They are purchasing 60,000 gauges for deployed forces and stateside training.
    - Other SOF units are purchasing and using gauges throughout training and operations. In these cases, Blast Gauge has become a key component of their strategy for managing TBI.
    - The Army has selected Blast Gauge as one of three components of its Integrated Soldier Sensor System (ISSS) requirement. DARPA is supporting the Army in designing and evaluating the ISSS.
    - While the Army is developing its objective solution (ISSS), it selected the Blast Gauge to be fielded to 18,000 Soldiers in OEF.
- Other services (including the Marine Corps Warfighting Laboratory), NATO partners, and Australia have independently evaluated the gauges and are deciding on next steps.
- Blast Gauge was cited as a DARPA advance directly supporting the Warfighter that contributed to the agency being awarded the Joint Meritorious Unit Award from the Secretary of Defense in 2012.
- Military officials have shown interest in examining the data and post-event analyses to ***gain insights into potential issues with brain injuries resulting from improper techniques and procedures for using equipment, including during training when most exposures occur.***

Revolutionizing Prosthetics (RP): Restoring Near-Natural Movement and Control of Upper Limbs

Technology Description and Program Goal

- When DARPA launched the Revolutionizing Prosthetics (RP) program in 2006, the state of upper-limb prosthetic technology was far behind lower-limb technology and was judged to be a more difficult medical and engineering challenge.
- The concept of a new system design may open the option for Service Members and others with upper-limb loss the chance to return to more fully active lives.
- The two research teams selected for the program, DEKA Integrated Solutions Corporation and the Johns Hopkins University Applied Physics Lab (APL), were tasked to:
    - Design and build anthropomorphic electromechanical upper extremity prostheses that mimic the capabilities of a natural arm for people with loss of an upper-limb.
    - Develop near-natural control modalities including exploration of direct neural control from peripheral nerves or the brain.
    - Investigate the ability to provide sensory feedback from sensors on the prosthesis through peripheral nerves or directly to the brain.
- Collaboration with Veterans Affairs, National Institutes of Health, Army Medical Research and Materiel Command, and Walter Reed National Military Medical Center has given more than75 users (amputees and tetraplegics) an opportunity to provide input to the design of both arm systems and supported regulatory submissions. In addition, Revolutionizing Prosthetics became the pilot program of the Food and Drug Administration's *Innovation Initiative* in 2011, providing a new pathway for novel medical technologies.

Transition Plan and Status

- Since February 2012, the University of Pittsburgh Medical Center, a subcontractor to the Applied Physics Lab (APL), has conducted a ***successful clinical study*** in which research participants living with tetraplegia were able to use neural signals from their brain to directly control the Modular Prosthetic Limb (MPL). ***This work has demonstrated that advanced prosthetics and direct neural interfaces can enable restoration of near-natural arm control to improve the quality of life for military personnel and civilians living with amputation or paralysis.***
- Veterans Affairs is conducting an independent 3-year home study of the DEKA Arm System. Upon Food and Drug Administration approval, the DEKA Arm System will be readied for commercialization. This transition plan includes development of advanced manufacturing and distribution to medical practitioners.
- The APL's MPL serves as a research platform and some MPL ***technology has transitioned to small robotic systems used in manipulating unexploded ordnance and suspicious objects.***

Smartphone Apps for the Dismounted Warfighter: Transformative Apps (TransApps)

Technology Description and Program Goal

- Today's Warfighters perform increasingly complex tasks but are still using outdated tools to access and share information on the battlefield. From a ground Soldier's perspective, little has changed in the last 20 years. They rely on inferior paper maps, written notes and reference materials, and voice radio transmissions to carry out their missions. Many technology advances that consumers take for granted have not made their way to the battlefield for a variety of reasons, especially security concerns and lack of robust high-bandwidth networks.

- With the TransApps program, DARPA aims ***to put today's commercial smartphone-grade capabilities in the hands of the Soldiers who most need them*** – those on daily patrols in theater – making their work much more effective and their lives easier and safer. In the field, the devices are providing Soldiers with an integrated ecosystem for situational awareness.
- Soldiers on patrol can keep up with fast-paced missions and changing environments by sharing and managing information in real time. That allows Warfighters and decision makers up and down the ranks and in various functions to share a common operating picture.
- They do this by using features and apps designed for their unique requirements: for example taking note of changes in the field – such as new bridges, structures, or civilians in an area – and sharing that information immediately with others who will direct and carry out future operations in that area.
- TransApps created a new agile development process, integration framework, and customized test cycles to allow rapid development of new applications, with new features and enhancements deployed quickly based on Soldiers' evolving requirements. ***When Soldiers need new apps, they can get them quickly – sometimes the very next day. This is a radical departure from how they have been operating.*** The TransApps ecosystem bridges old and new, allowing future technologies to work seamlessly with legacy radios and information systems. By endowing commercial off-the-shelf (COTS) smartphones with custom multilayered security and agile development processes modified for the tactical community, TransApps is creating a scalable and sustainable infrastructure template.

Transition Plan and Status

- A 4-year program that concludes in FY 2014, ***TransApps was first fielded to Afghanistan in 2011; within 18 months, more than 3,000 systems were deployed to the battlefield, supporting all Army maneuver operations theater-wide.***
- In FY 2014, DARPA is working with the Army Nett Warrior Program to fully transition TransApps capabilities into the enduring Program of Record, as part of the Army's efforts to get new technologies into the hands of the Soldier.
- Other organizations and agencies are preparing to transition program components. These include the Application Testing Portal for streamlined security and performance analysis of mobile applications, as well as TransApps' custom imagery processing and configuration tools, which empower Soldiers to manage their own maps based on mission requirements.

Persistent Close Air Support: Faster and There When Troops Need It

Technology Description and Program Goal

- To maintain a decisive tactical advantage in 21st-century combat, Warfighters need to safely, rapidly, and collaboratively deploy ordnance against elusive mobile targets. Unfortunately, air-ground fire coordination, referred to as Close Air Support, or CAS, has changed little since World War I.
- Pilots and dismounted ground agents can focus on only one target at a time and often must ensure they hit it using just voice directions and a paper map. In complex environments, it can take up to an hour to confer, get in position and strike – time in which targets can attack first or move out of reach.
- DARPA created the Persistent Close Air Support (PCAS) program to enable dismounted ground agents and combat aircrews to share real-time situational awareness and weapons systems data.
- The system DARPA developed and tested ***enables ground agents to quickly and positively identify multiple targets simultaneously.*** Ground and air forces would jointly select precision-guided ordnance that best fits each target and minimizes collateral damage and friendly fire.

Finally, both parties would authorize weapons deployment.
- Benefits would include reduction in time from calling in a strike to target hits reduced from as much as 60 minutes to just 6 minutes; direct coordination of airstrikes by a ground agent from manned or unmanned air vehicles; improved speed and survivability of ground forces engaged with enemy forces; and use of smaller, more precise munitions against smaller and moving targets in degraded visual environments. Another benefit is graceful degradation; if one piece of the system fails, Warfighters still retain capability of more basic functionality.

Transition Plan and Status

- In early 2013, DARPA deployed 500 Android tablets equipped with PCAS-Ground situational awareness software to units stationed in Afghanistan. An operator on the ground – with a tablet and voice radio – communicated with a pilot who had a tablet in the cockpit about imagery they both share on their tablets. (The program also developed a networked solution that allows even more rapid information sharing.)
- ***Field reports show that PCAS-Ground replaced those units' legacy paper maps, dramatically improving ground forces' ability to quickly and safely coordinate air engagements.***
- The program, which began in FY 2010 and concludes in early 2015, is in the flight-testing phase, which concludes with live fire demonstrations.
- Elements of PCAS, particularly the JTAC ground software, are seeing traction among various JTAC-related programs of record across the Services.

ARATI PRABHAKAR
DIRECTOR
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

Arati Prabhakar is the director of the Defense Advanced Research Projects Agency.

Dr. Prabhakar has spent her career investing in world-class engineers and scientists to create new technologies and businesses. Her first service to national security started in 1986 when she joined DARPA as a program manager. She initiated and managed programs in advanced semiconductor technology and flexible manufacturing, as well as demonstration projects to insert new semiconductor technologies into military systems. As the founding director of DARPA's Microelectronics Technology Office, she led a team of program managers whose efforts spanned these areas, as well as optoelectronics, infrared imaging and nanoelectronics.

In 1993, President William Clinton appointed Dr. Prabhakar director of the National Institute of Standards and Technology, where she led the 3,000-person organization in its work with companies across multiple industries.

Dr. Prabhakar moved to Silicon Valley in 1997, first as chief technology officer and senior vice president at Raychem, and later vice president and then president of Interval Research. From 2001 to 2011, she was a partner with U.S. Venture Partners, an early-stage venture capital firm. Dr. Prabhakar identified and served as a director for startup companies with the promise of significant growth. She worked with entrepreneurs in energy and efficiency technologies, components for consumer electronics, and semiconductor process and design technology.

Dr. Prabhakar received her Doctor of Philosophy in applied physics and Master of Science in electrical engineering from the California Institute of Technology. She received her Bachelor of Science in electrical engineering from Texas Tech University. She began her career as a Congressional Fellow at the Office of Technology Assessment.

Dr. Prabhakar has served in recent years on the National Academies' Science Technology and Economic Policy Board, the College of Engineering Advisory Board at the University of California, Berkeley, and the red team of DARPA's Defense Sciences Research Council. In addition, she chaired the Efficiency and Renewables Advisory Committee for the U.S. Department of Energy. Dr. Prabhakar is a Fellow of the Institute of Electrical and Electronics Engineers, a Texas Tech Distinguished Engineer, and a Caltech Distinguished Alumna.

WITNESS RESPONSES TO QUESTIONS ASKED DURING THE HEARING

MARCH 26, 2014

RESPONSE TO QUESTION SUBMITTED BY MR. THORNBERRY

Mr. SHAFFER. In response to a December 2010 request by then-Vice Chairman of the Joint Chiefs of Staff, General Cartwright for a comprehensive review of directed energy (DE) policy, then-Under Secretary of Defense for Policy, James Miller, issued an interim policy memorandum on February 14, 2012. That memorandum recognized the operational benefits associated with currently fielded DE technologies and expressed support for continued development in accordance with our laws, treaty commitments, and policies. The policy requires OSD-level review and approval prior to the operational use of new directed energy weapons. The review and approval process (RAP) is now detailed in Chairman of the Joint Chiefs of Staff Manual (CJCSM) 3230.01, "Directed Energy Weapon Initial Operational Employment Review and Approval Process." The DE RAP requires and takes into account legal reviews, concepts of employment, rules of engagement, tactics, potential collateral damage and human effects, proposed public affairs guidance, and other relevant information. DE RAP requests are submitted by the combatant command; RAP-endorsed requests are to be forwarded to the Secretary of Defense (SecDef) for consideration and SecDef approval or forwarding to the President for approval as appropriate. [See page 23.]

QUESTIONS SUBMITTED BY MEMBERS POST HEARING

MARCH 26, 2014

QUESTIONS SUBMITTED BY MR. THORNBERRY

Mr. THORNBERRY. Recent media reports suggest we may lose more domestic microelectronics foundries. How will the Department ensure we have access to an assured trusted foundry?

Mr. SHAFFER. The U.S. Department of Defense (DOD) relies upon microelectronics for enabling components in our military systems. The Department depends upon access to a vibrant and innovative semiconductor industry and an assured supply of legacy components through a trusted supply chain. The Department is actively engaged in working with industry on initiatives that include the Trusted Supplier Accreditation Program and the Trusted Foundry Program, which combined are commonly labeled the Trusted Supply Program.

The Trusted Supply Program, administered by the Defense Microelectronics Activity (DMEA), is a process of accreditation that ensures that developers of defense systems have access to trusted microelectronics components across a wide range of technologies, from state-of-the-art to state-of-the-practice to legacy. To satisfy the state-of-the-art semiconductor requirements, DOD worked with NSA's Trusted Access Program Office, in funding a contract with IBM to provide leading edge access to IBM's foundries. Trusted state-of-the-practice (SOTP) technology suppliers are accredited for Trust by DMEA, according to established Trust criteria.

Legacy components are transitioned out of production when the commercial market declines. DMEA has put in place a process to acquire intellectual property for technologies and processes when their commercial markets drop off. This allows the Department to provide a source of last resort capability at DMEA to produce small quantities of microelectronics parts when no commercial source is available.

The DOD has a strategy to provide trusted and assured microelectronic parts throughout the chain of supply. Using the commercial industrial base, the DOD has in place the ability to access SOTA parts from the Trusted Foundry Program, SOTP parts from the trusted suppliers program, and legacy parts from DMEA when no longer available from industry.

Mr. THORNBERRY. In your testimony, you mention an effort through the Defense Technical Information Center to improve our understanding of global technology development. Could you please describe that effort in a bit more detail?

Mr. SHAFFER. We are developing semi-automated Technology Watch and Horizon Scanning (TW/HS) capabilities to forecast the evolution of known science and technologies and their applications as well as the emergence of new concepts and technologies with disruptive potential. Thousands of companies are using business analytics methods to forecast events in their domains, including science and technology (S&T). Forecasting S&T is also of interest to many groups within the USG. In the TW/HS program, we are evaluating and leveraging existing approaches, tools, and data to detect the initiation of disruptive S&T advances as early as possible. Many existing approaches use only one type of data or use a purely data-driven approach and big data analytics to detect predictive trends. We are working to find, test, and implement theory-based models that use data in a meaningful way to forecast S&T trends and disruptions. We are working with the Defense Technical Information Center (DTIC) to deploy and test a system that provides an automated capability to identify signals that may be associated with disruptive S&T advances that have potential defense implications. The system can be used to monitor the evolution of known technologies, including the maturation of emerging technologies and new applications of existing technologies (technology watch), and the emergence of new scientific concepts and technologies with disruptive potential (horizon scanning). The TW/HS prototype comprises a computing architecture that supports multiple algorithmic analyses of varied types of input data, an illustrative end-user interface, and an initial method for system test and evaluation. The system analyzes indicators and predictors of technology breakthroughs and allows for the sharing of analysis results between multiple users. Feedback from users of the system may guide the development of a next-generation system. The current system is a prototype, whose development, test, and evaluation are expected to inform the development of a next-generation approach that will incorporate additional analytics methods and will be informed by a theory-based approach to technology forecasting.

Mr. THORNBERRY. Part of our Defense Reform Initiative is to look at acquisition reform, and as part of that, we are interested in understanding how S&T supports the Department's goal of improving acquisition outcomes and meeting the guidance of the Better Buying Power 2.0 initiatives. Could each of you give us an example in each of your organizations of how you are applying S&T to these problems?

Mr. SHAFFER. Acquiring the weapon systems we need to outpace our adversaries requires not only a highly competent Science and Technology (S&T) community, but methods to effectively tap the community. The Assistant Secretary of Defense (Research & Engineering) (ASD (R&E)) has many programs and initiatives that reach out to the R&E enterprise and beyond to find and develop affordable weapon systems. These programs align well with several tenants of Better Buying Power (BBP) 2.0. BBP 2.0 stresses the importance of seeking cost reductions throughout a product's lifecycle. ASD (R&E)'s Foreign Comparative Test (FCT) program searches the globe to find suitable and cost-effective solutions to warfighter needs. A primary focus of that search is for replacements to legacy systems and components that can no longer be affordably manufactured in the United States. For example, the FCT program uncovered an H–53 helicopter generator control unit used on a German version of the H–53 that was less expensive and more reliable than the legacy version. During the FCT's 33 year history, the DOD's $1.23 billion investment has resulted in $10.9 billion in weapons systems procurements and an estimated cost avoidance of $7.6 billion. Several ASD (R&E) programs achieve affordability aims by reducing barriers to entry for innovative companies. The Innovation Outreach initiative provides a vehicle to identify sources of novel solutions. One such solution is the iTClamp, which provides medical first responders with an alternative to the tourniquet. iTClamp is a low cost (less than a $100) medical device able to constrain blood flow to the wound while rerouting blood to the far end of the wounded extremity, increasing the chance of saving the limb. Instant Eye is another solution uncovered by an ASD (R&E) program. Instant Eye is a small quad-copter, unmanned system that costs less than a $1,000, is field repairable, and can deliver real-time surveillance video to a tactical unit. BBP 2.0's emphasis on eliminating redundancy within warfighter portfolios inspired the CLOUDBREAK initiative. CLOUDBREAK's vision is to provide an easily accessible "app store" the combatant commands (CCMD) can use to acquire Command and Control (C2) solutions. Rather than each CCMD purchasing a custom solution, CLOUDBREAK provides a suite of solutions that can be inexpensively tailored to meet the needs of each user.

Mr. THORNBERRY. Do the provisions contained within the SBIR Reauthorization Act contained within the FY 12 NDAA give you sufficient authority to ensure that SBIR funded technologies have an opportunity to transition to acquisition programs of record? Describe the DOD's plan to implement those provisions.

Mr. SHAFFER. Yes. As one initiative, we have added to DODI 5000.02, page 57, Table 2. Milestone and Phase Information Requirements the following: "Program managers will establish goals for applying SBIR and STTR technologies in programs of record. For contracts with a value at or above $100 million, program managers will establish a goal for the transition of Phase III technologies in subcontracting plans, and report the number and dollar amount of contracts entered into for Phase III SBIR or STTR projects."

In addition, each major DOD acquisition program designates an individual who is (a) knowledgeable about the technology needs of the acquisition program and (b) responsible for technology infusion into the program, to serve as the program's SBIR Liaison. These Liaisons undertake to ensure that appropriate SBIR technologies are considered for acquisition programs.

Mr. THORNBERRY. Each of the Services has described prototyping and requirements maturation processes to help support future acquisition programs. Why are those tools important? How do ensure technology transition for successful S&T initiatives to get them to acquisition program managers and program executive offices?

Ms. MILLER. Targeted technology maturation and prototyping has emerged as an overall area of emphasis within the Army's laboratories and research, development and engineering centers (RDECs). These activities help to better inform requirements for new systems, as well as drive down the risk of integrating new technologies, by demonstrating mature solutions that are technically achievable and affordable. In conducting maturation and prototyping earlier in the acquisition lifecycle, we can identify and address areas of risk before the government commits more significant levels of funding to a Program of Record (PoR). Ultimately, it is much more cost-effective to prove out innovative concepts and capabilities in Science and Technology (S&T) than it is under formal program acquisition.

One example is the Army's Technology Maturation Initiative (TMI) (Program Element 0604115A) which aligns S&T and acquisition partners under a coordinated effort to prove out emerging, but needed, technology components and facilitate their

transition to PoRs. It matures high-payoff S&T products beyond traditional S&T technology readiness levels in order to drive down acquisition costs and risks, and increase transition success.

These efforts have become especially important as the Army heads into a funding downturn. We are planning to invest in technology maturation and prototyping efforts to prepare the Army to capitalize on S&T investments as we come out of the acquisition funding "bathtub" near the end of the decade. For Budget Activity 4 authorities, we are using these resources to target areas where acquisition programs intended to provide necessary capabilities have been delayed, such as assured Position, Navigation and Timing, the Future Infantry Fighting Vehicle, and Active Protection Systems.

By engaging key stakeholders from the requirements, technology, acquisition and resourcing communities to select and oversee the Technology Maturation Initiative and other prototyping efforts, we are able to prioritize and coordinate efforts that will best enable the integration of innovative capabilities in to planned acquisition programs. In this way, these efforts directly support and apply the Army's 30-year acquisition planning construct.

Mr. THORNBERRY. Part of our Defense Reform Initiative is to look at acquisition reform, and as part of that, we are interested in understanding how S&T supports the Department's goal of improving acquisition outcomes and meeting the guidance of the Better Buying Power 2.0 initiatives. Could each of you give us an example in each of your organizations of how you are applying S&T to these problems?

Ms. MILLER. One example is Army S&T's Technology Maturation Initiative (TMI) (Program Element 0604115A). Created in FY12, TMI developed a strategic partnership between S&T and the acquisition community to facilitate the transition of key technologies to Programs of Record and enables the Army to fulfill the risk-reduction goals laid out by the Weapons Systems Acquisition Reform Act (WSARA) and DODI 5000.02. By engaging program managers early in the technology development process and collaboratively defining technology, performance goals and acceptance testing, we facilitate a more successful insertion of mature technology for emerging capabilities. Reaching technical maturity prior to integration reduces program risk and eliminates excess costs.

Controlling costs throughout the product lifecycle is another area Army S&T is placing additional focus. By designing technologies with reliability and manufacturability in mind, we can reduce the cost and time associated with redesign when these technologies transition from the S&T domain into formal Programs of Record, resulting in lower developmental costs and potentially faster acquisition. The Army ManTech (Program Element 0708045A) investment develops and demonstrates manufacturing processes to enable producibility and affordability for emerging technologies and subsystems. For example, the Manufacturing of Flexible Electronics for Large Area Sensors project will develop the U.S. manufacturing base for large area flexible electronic sensor technology fabricated on plastic substrates. This will provide capability through the integration of light weight, rugged sensors into digital radiography panels for Soldier portable Explosive Ordinance Disposal inspection and forensics applications.

Mr. THORNBERRY. Do the provisions contained within the SBIR Reauthorization Act contained within the FY 12 NDAA give you sufficient authority to ensure that SBIR funded technologies have an opportunity to transition to acquisition programs of record? Describe the DOD's plan to implement those provisions.

Ms. MILLER. The SBIR Reauthorization Act gives the Army sufficient authority to ensure that our SBIR funded technologies have the opportunity to transition. There are over 20 changes resulting from reauthorization. The key statutory language relevant to this discussion are:

1) All acquisition programs must report where they are incorporating SBIR technologies as part of their subcontracting plan,

2) DOD must set goals for SBIR inclusion in acquisition programs,

3) DOD is authorized to incentivize Program Executive Offices and prime contractors for all awards greater than $100M to include SBIR technologies.

While none of these changes have been fully implemented yet, the Army is participating in a SBIR Commercialization Working Group with the Department, and all DOD SBIR program managers create a model that sets the standard for transitioning SBIR developed technology. The reporting in item 1) above should be relatively straight-forward once incorporated into contract requirements. Setting goals is more challenging because in partnership with our sister Services we must first establish a baseline and then determine reasonable and meaningful metrics to measure transition performance for evaluation of effectiveness of the incentives. Item 3) is currently being evaluated by the Department for feasibility and approach.

Mr. THORNBERRY. The Army recently completed successful testing of a High Energy Laser Mobile Demonstrator (HEL–MD). What is the Army's plan for developing and fielding directed energy weapons? What additional testing do you have planned for the HEL–MD system, and how will all of that testing fit into the Army's plans for a directed energy program of record?

Ms. MILLER. The recent demonstration was an interim demonstration of a High Energy Laser mobile platform capability against light mortars and Unmanned Aerial Systems (UASs). Additional development of the laser, beam control, power, thermal management, and fire control subsystems is planned along with additional incremental demonstrations using the laser-integrated mobile platform through FY22. The incremental demonstrations will validate 50kW Counter-Rockets Artillery and Mortars (C–RAM) and Counter-UAS (C–UAS) performance in FY17, 100kW C–RAM, C–UAS and Cruise Missile Defense performance in FY20, and a culminating demonstration of Integrated Force Protection Capability—Increment 2 Intercept (IFPC–2I) level performance in FY22. These demonstrations will validate required performance and facilitate transition to a future increment of IFPC–2I with a planned technology insertion in the 2028–2032 timeframe.

Mr. THORNBERRY. Each of the Services has described prototyping and requirements maturation processes to help support future acquisition programs. Why are those tools important? How do ensure technology transition for successful S&T initiatives to get them to acquisition program managers and program executive offices?

Admiral KLUNDER. The Department of Navy (DoN) has a well-defined process for developing and transitioning new capabilities to future acquisition program called the Future Naval Capabilities (FNC) program. This process, initiated by the Navy and Marine Corps in 2002, continues to be refined in order to maintain alignment with DoN guidance and priorities. The FNC program uses a number of management tools and best practices that have a demonstrated record of success as confirmed by a recent GAO report (GAO–13–286, March 2013). These tools are important because they ensure DoN financial resources being expended on the development of demonstration prototypes and new innovative warfighting capabilities are fully aligned with senior Navy and Marine Corps leadership priorities. The selection of specific FNC S&T initiatives (Enabling Capabilities) follows a formal requirements-driven process that is governed by a set of signed business rules which are reviewed an updated roughly every two years to maintain currency. This documented process ensures that Navy & Marine Corps leadership are directly involved in the oversight, management and execution of the program during all phases of development. All funded S&T initiatives are competitively selected by a 3-star Technology Oversight Group (TOG), chartered by a (4-star level) DoN RDT&TE Corporate Board. TOG members represent the Requirements, Acquisition, S&T and Fleet/Forces communities of the Navy and Marine Corps. Each year the TOG releases an updated set of Technology Gaps that establish mission capability shortfall areas that can be traced back to the warfighting needs that have been independently assessed by the appropriate CNO and CMC assessment organizations. All FNC S&T initiatives link to an appropriate TOG Technology Gap and are managed by 1 of 9 Integrated Product Teams (IPTs). These IPTs are 2-star oversight boards that consist of Flag Officers/Senior Executive Service members representing the S&T, Acquisition, Navy and Marine Corps Resource/Requirements and Fleet Force Communities. The roles and responsibilities for each IPT member are defined in the FNC Business Rules, which are promulgated by the TOG. IPT Resource Sponsors, for example, have the responsibility to ensure that RDT&E resources are programmed to receive and integrate the FNC technology Products approved by the TOG. The IPT Acquisition Sponsor is responsible to ensure that Program of Record technology insertion windows are tracked and that S&T technology deliverables can be incorporated into their acquisition PORs as planned. By design, the process strengthens transition coordination between the fleet/force, S&T, acquisition and resources/requirements communities. The DoN process ensures successful FNC S&T initiatives transition to program executive offices and acquisition program mangers by focusing on the use of negotiated Technology Transition Agreements (TTAs). Each funded FNC S&T initiative is backed by a TTA that has been negotiated, agreed upon, and signed by appropriate managers within the Resources and Requirements community, establishing the requirements and providing funds for the acquisition PORs), the S&T community, (developing the technology solution and demonstration prototypes) and Acquisition community (transitioning the capability into an existing or emerging Program of Record). A critical aspect of this process is that DoN S&T funding is not released without an approved, signed TTA for each of these initiatives. Each of the TTAs are reviewed, updated and reaffirmed annually. This process ensures all parties involved in establishing the requirements, developing the solution, and transitioning

that capability to the warfighter remain engaged throughout the development cycle. This process has proven to be highly successful.

Mr. THORNBERRY. Part of our Defense Reform Initiative is to look at acquisition reform, and as part of that, we are interested in understanding how S&T supports the Department's goal of improving acquisition outcomes and meeting the guidance of the Better Buying Power 2.0 initiatives. Could each of you give us an example in each of your organizations of how you are applying S&T to these problems?

Admiral KLUNDER. The Department of Navy (DoN) has a well-defined process which supports Better Buying Power 2.0 initiative. It is the Department's Manufacturing Technology (MANTECH) program which aggressively targets cost savings efforts in several major acquisition programs.

One success story is the VIRGINIA Class Submarine (VCS) Affordability Initiative. Initiated in FY06 with a focus on acquisition cost savings, ManTech was a key contributor to the VIRGINIA Class cost reduction effort. ManTech, to date, has facilitated $27.75M per hull of realized cost savings.

Navy ManTech is also making a significant impact on the F–35 Joint Strike Fighter (JSF) acquisition. Program Executive Office for JSF has credited Navy ManTech with over $700 million in savings for the Department of Defense purchase of F–35 aircraft for the current project portfolio. Example projects contributing to this savings include automated fiber placement for advanced F–35 materials projected to save $100 million and JSF canopy thermoforming automation projected to save between $75 and $125M depending on the number of spares produced over the life cycle.

Mr. THORNBERRY. Do the provisions contained within the SBIR Reauthorization Act contained within the FY 12 NDAA give you sufficient authority to ensure that SBIR funded technologies have an opportunity to transition to acquisition programs of record? Describe the DOD's plan to implement those provisions.

Admiral KLUNDER. Yes. Two sections in the Reauthorization Act increase our Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) programs' authority regarding technology transition. Section 5121 increases the technical assistance we can provide to small businesses through commercialization experts in Phases I and II for both SBIR and STTR. Section 5141 dedicates an administrative funding pool to increased transition management support by government sources—in Department of the Navy's case, SBIR/STTR transition managers at program executive offices and acquisition program offices. A third provision—Section 5122—which mandates reporting on SBIR/STTR transition goals and performance metrics, is expected to further enhance our technology transition authority. Execution of Section 5122 awaits action by the Secretary of Defense's Office of Small Business Programs.

Mr. THORNBERRY. What is the Air Force's plan for developing and fielding directed energy weapons? Is there currently a marquee Air Force directed energy program?

Dr. WALKER. The Air Force Science and Technology (S&T) Program has a well-defined plan for developing and demonstrating a wide range of technologies necessary to transition DEWs to the warfighter. The DEW technologies are expected to support various Air Force missions, such as counter electronics, aircraft self-protection, and air-to-air and air-to-ground engagements.

For example, the Air Force is collaborating with DARPA and the Missile Defense Agency to develop laser and beam control technologies for a potential aircraft self-protection laser pod demonstration in the FY19 timeframe and an air-to-air defensive pod demonstration in the FY21 time frame. The Air Force is also working with the High Energy Laser Joint Technology Office and others to address the needs for a future air dominance demonstration. Key to this effort is our major activity addressing the aero-effects issues that have hampered previous airborne laser demonstrations.

In the area of high power microwaves, the Air Force marquee S&T program, Counter-electronics High Power Microwave Advanced Missile Project (CHAMP), was a very successful Joint Capability Technology Demonstration (JCTD). Within S&T, the Air Force is addressing technologies for a more advanced version that will fit in smaller platforms.

The Air Force is using results from this successful JCTD to inform an effort known as Non-Kinetic Counter Electronics (NKCE), which is currently in pre-Materiel Development Decision phase, and seeks to have a procured and operational weapon system to support requirements of Combatant Commanders in the mid-2020 time frame.

Mr. THORNBERRY. Each of the Services has described prototyping and requirements maturation processes to help support future acquisition programs. Why are those tools important? How do ensure technology transition for successful S&T initiatives to get them to acquisition program managers and program executive offices?

Dr. WALKER. The Air Force's S&T investments develop technology-based options and reduce the technical risks of current and future acquisition programs. To efficiently and effectively accomplish this, it is essential the requirements and acquisition communities collaboratively develop potential solutions to operational capability needs, and ensure that objective technical assessments of the viability and risks associated with these concepts are made available to inform requirements and acquisition decision points and milestones.

An example of an initiative the Air Force is undertaking to achieve greater levels of early interaction between the operational users, acquisition centers, and technologists are Capability Collaboration Teams (CCT). CCTs are established by the Air Force Major Commands (MAJCOM) that have responsibility to organize, train, and equip the current and future Air Force. CCTs provide a method for the MAJCOMs [warfighters], the acquisition centers [acquirers], and the Air Force Research Laboratory [technologists] to integrate operational capability needs and requirements with acquisition priorities and technology options. CCTs work collaboratively to understand MAJCOM-documented capability needs that may require a materiel solution and determine if S&T is required for associated technology needs and then formulate potential S&T solutions (e.g., technology development, risk reduction, demonstration, or maturation projects) to address the identified S&T needs. In some cases, prototyping is useful to demonstrate potential capabilities in an operationally relevant environment to the warfighter. Prototyping supports risk reduction and maturation of technology by minimizing programmatic risks and reducing development cycle time. The result is that our S&T efforts will be scoped and structured to prove out high risk technologies necessary for a follow-on acquisition program thereby reducing cost, schedule, and performance risks.

Mr. THORNBERRY. Part of our Defense Reform Initiative is to look at acquisition reform, and as part of that, we are interested in understanding how S&T supports the Department's goal of improving acquisition outcomes and meeting the guidance of the Better Buying Power 2.0 initiatives. Could each of you give us an example in each of your organizations of how you are applying S&T to these problems?

Dr. WALKER. The Air Force's S&T investments develop technology-based options and reduce the technical risks of current and future acquisition programs. As identified in the Better Buying Power 2.0 initiative to control costs throughout the product lifecycle, it is essential the requirements and acquisition communities collaboratively develop potential solutions to operational capability needs, and ensure that objective technical assessments of the viability and risks associated with these concepts are made available to inform requirements and acquisition decision points and milestones. The Air Force continues to improve its S&T planning processes to build and solidify these effective and efficient relationships between our requirements and acquisition communities.

An example of an initiative the Air Force is undertaking to achieve greater levels of early interaction between the operational users, acquisition centers, and technologists are Capability Collaboration Teams (CCT). CCTs are established by the Air Force Major Commands (MAJCOM) that have responsibility to organize, train, and equip the current and future Air Force. CCTs provide a method for the MAJCOMs [warfighters], the acquisition centers [acquirers], and the Air Force Research Laboratory [technologists] to integrate operational capability needs and requirements with acquisition priorities and technology options. CCTs work collaboratively to understand MAJCOM-documented capability needs that may require a materiel solution. CCTs determine if S&T is required and then formulate potential S&T solutions (e.g., technology development, risk reduction, demonstration, or maturation projects) to address the identified needs. Air Force S&T efforts are scoped and structured to prove out high risk technologies, which reduce the cost, schedule, and performance risks associated with follow-on acquisition programs.

Mr. THORNBERRY. Do the provisions contained within the SBIR Reauthorization Act contained within the FY 12 NDAA give you sufficient authority to ensure that SBIR funded technologies have an opportunity to transition to acquisition programs of record? Describe the DOD's plan to implement those provisions.

Dr. WALKER. Yes. The provisions contained within the SBIR Reauthorization Act in the FY 12 NDAA give sufficient authority to transition SBIR funded technologies into acquisition programs of record. However, the availability of funds within most programs to support SBIR transitions are generally non-existent. A separate Program Element to focus exclusively on SBIR transition efforts would be difficult to justify, since efforts are often not selected until the year-of-execution. Obtaining authorities to use a portion of existing SBIR funds as a set-aside to support SBIR transitions would ensure the availability of monies to help the Air Force transition SBIR developed technologies into programs of record. The Air Force recommends obtaining the authority to use all or a portion of the increase in RDT&E SBIR assess-

ments (2.5%–3.2%) on "Phase III" transition contracts. Current constraints only allow the use of SBIR funds to mature technology; this leaves the full burden of transition on the budgets of programs of record. Using a portion of the increased RDT&E SBIR expenditure assessment on Phase III contracts would enable a cost-sharing environment and open the door for a dramatic increase in the transition of SBIR developed technologies.

The Air Force continues to work with the Office of the Secretary of Defense and the other Services to implement the provisions of the SBIR/STTR Reauthorization. For example, the Air Force has been updating and institutionalizing internal training programs to better educate existing and new small business contractors in order to increase their awareness and to solicit their early involvement. The Air Force has also been working with Defense Acquisition University to update defense-wide certifications and continuous learning opportunities. Both of these support an education goal to help change the culture by showing the added value of small business participation.

Mr. THORNBERRY. Part of our Defense Reform Initiative is to look at acquisition reform, and as part of that, we are interested in understanding how S&T supports the Department's goal of improving acquisition outcomes and meeting the guidance of the Better Buying Power 2.0 initiatives. Could each of you give us an example in each of your organizations of how you are applying S&T to these problems?

Dr. PRABHAKAR. Our role at the Defense Advanced Research Projects Agency (DARPA) is to make the pivotal early investments that change what is possible for breakthrough national security capabilities. Two examples include the Long Range Anti-Ship Missile (LRASM) and the Systems of Systems Integration Technology and Experimentation (SoSITE) programs.

Long Range Anti-Ship Missile (LRASM):

The LRASM program began in response to an urgent capability need identified by the Navy in 2008. The program objectives were to demonstrate a fully integrated tactically representative weapon system to address this capability gap as early as possible. Decomposing the urgent need in to technologies objectives, the LRASM program focused on reducing the dependence on intelligence, surveillance and reconnaissance (ISR) platforms, network links, and Global Positioning System (GPS) navigation in electronic warfare environments. Autonomous guidance algorithms will allow the LRASM to use less-precise target cueing data to pinpoint specific targets in the contested domain. The program also focuses on innovative terminal survivability approaches and precision lethality in the face of advanced counter measures.

To accomplish this, the program office created a small, dedicated team that maintained a single focus of program execution comprised of government, Systems Engineering and Technical Assistance (SETA) contractors, Federally Funded Research and Development Centers, and Industry. A "skunkworks" mentality was adopted by all parties in order to maintain cost and schedule while attacking many high risk items. The program office met the rapid development objectives by conducting two flight demonstrations, each with resounding success. The LRASM successfully separated from the aircraft, navigated through a series of preplanned waypoints, and then transitioned to an autonomous mode while seeking the target it had been instructed to attack. The missile detected, identified, and tracked the mobile ship target at extended range; transitioned to guidance on the terminal sensor; and impacted the target with a miss distance well within acceptable error probabilities.

With an empowered and unencumbered program manager and support staff, the DARPA team was able to streamline the decision making process by including the appropriate stakeholders as part of the effort rather than as external "decision boards." By eliminating redundant processes and reviews, the Agency was able to reach out to the Services and inject synergy at the technical base level: LRASM was able to leverage the essential capabilities inherent in each Service to effect a dynamic demonstration. As a forcing element, the LRASM program was able to build a strong and lasting partnership with the Service requirements community, as well as the warfighting organizations at the initiation of the program. This provided a base capability that seamlessly flowed into the working requirements for the Offensive Anti-Surface Warfare mission area. By providing a full-time requirements/concept of operations SETA to work closely with the warfighter and the requirements community, there was a consolidated perspective during the definition and generation of requirements. This interaction at the initiating stages of the program (during the true Science and Technology phase) allowed early flow down of warfighter needs and system designs at inception and refinement of technological applicability. This allowed the LRASM program to better balance user needs within technology and cost constraints, as well as informing the warfighter of future capability and timeline availability.

In light of the successful demonstrations and technical maturity of the system, the Office of the Secretary of Defense issued a Resource Management Directive to fully fund a rapid acquisition effort to field the LRASM on the B–1B in fiscal year 2018 and on the F/A–18 Hornet in fiscal year 2019. DARPA's early investment in requisite technologies enabled the Department of Defense to rapidly field a next generation capability to support the warfighter. In addition, these investments have significantly increased the state of the art, better positioning the accelerated acquisition effort to deliver on cost and schedule.

System of Systems Integration Technology and Experimentation (SoSITE):

DARPA has initiated the SoSITE program to develop the capability to operate low-cost, simpler platforms in cooperation with more capable platforms as integrated force structures. This approach enables the U.S. military to acquire the capabilities to maintain dominance over potential peer adversaries, who are investing in technologies to produce high-end systems in large quantities.

DARPA is also developing supporting mission system technologies to make distributed architectures possible. These technologies include investments in adaptive communications and networking, autonomy, and command and control that contribute to interoperability. They promote rapid fielding of new systems and integration into the force structure, and control operational cost and complexity.

DARPA is partnering closely with Service and Office of the Secretary of Defense (OSD) open architecture initiatives. Integration tools developed by SoSITE and other programs will facilitate streamlined application of open architectures to future acquisition programs and enable the expansion and adaptation of open architecture standards with a minimum of additional bureaucratic burden.

The DARPA System of Systems strategy contributes directly to the goals of the Better Buying Power 2.0 initiative by:

- Enabling highly affordable weapon systems to achieve military effectiveness as part of an integrated architecture
- Providing the means to manage requirements across an architecture to help control costs of more capable platforms
- Providing tools to deploy complex architectures more efficiently, helping to control life-cycle operational costs
- Creating opportunities and competition at all tiers of the industrial base to encourage productivity and innovation
- Promoting wider adoption of open architecture standards and practices while minimizing bureaucratic burden.

Mr. THORNBERRY. Do the provisions contained within the SBIR Reauthorization Act contained within the FY 12 NDAA give you sufficient authority to ensure that SBIR funded technologies have an opportunity to transition to acquisition programs of record? Describe the DOD's plan to implement those provisions.

Dr. PRABHAKAR. DARPA defers to ASD(R&E), which is the lead for SBIR implementation.

The ASD(R&E), Mr. Shaffer, states: Yes. As one initiative, we have added to DODI 5000.02, page 57, Table 2. Milestone and Phase Information Requirements the following: "Program managers will establish goals for applying SBIR and STTR technologies in programs of record. For contracts with a value at or above $100 million, program managers will establish a goal for the transition of Phase III technologies in subcontracting plans, and report the number and dollar amount of contracts entered into for Phase III SBIR or STTR projects."

In addition, each major DOD acquisition program designates an individual who is (a) knowledgeable about the technology needs of the acquisition program and (b) responsible for technology infusion into the program, to serve as the program's SBIR Liaison. These Liaisons undertake to ensure that appropriate SBIR technologies are considered for acquisition programs.

QUESTIONS SUBMITTED BY MR. PETERS

Mr. PETERS. Earlier this year, a number of leading research universities, including UC San Diego, UCLA, Stanford, and Cal Tech sent a letter to Secretary James and Under Secretary Kendall, expressing several significant concerns regarding the potential move of the Air Force Office of Scientific Research (AFOSR) from its current headquarters in Arlington, VA to the Wright-Patterson Air Force Base. [Letter available upon request.]

I am concerned that a move to Wright-Patterson could lead to a change in the thrust of AFOSR's funding from basic research at universities to applied research at Air Force laboratories. This would jeopardize the many opportunities for innovation that are unique to the AFOSR-university partnership.

Has the Air Force studied other circumstances where basic research program managers and operational personnel are located in the same facility? If so, what are the lessons from those experiences? If not, does the Air Force intend to undertake such studies prior to a final decision? Has the Air Force conducted an analysis to determine what, if any, safeguards should be put in place to ensure that AFOSR program managers will continue to address long-range, basic research and not be influenced by the immediate needs of lab personnel? Has the Air Force analyzed the benefits of having AFOSR in close proximity to the Pentagon, DARPA, the DNI, NSF and other research agencies, and how those benefits would be impacted by separating AFOSR geographically from these other agencies?

Dr. WALKER. The Air Force has decided not to relocate AFOSR to Wright-Patterson Air Force Base (WPAFB). This decision was reached after a deliberative process that included assessments of the cost of operation, risks to the basic research mission, and benefits to the basic research mission based on two potential courses of action (1. AFOSR remains in Ballston, VA and 2. AFOSR moves to WPAFB).

The Commander of Air Force Materiel Command (AFMC) directed headquarters AFMC staff to complete a Cost Benefit Analysis (CBA) prior to taking any action. The Air Force determined the majority of savings identified in the CBA were the result of reduced support manpower and that some of these savings may be obtained in place. Additionally, preliminary findings identified risk to personnel skills and access to collaborators, such as NSF, DARPA, the Office of Naval Research, Department of Energy, National Institute of Standards and Technology, and NASA.

The Air Force also developed a public Request for Information (RFI) to assess the impact of the location of AFOSR as perceived by the wider academic community. Based on these assessments, the Air Force decided to maintain AFOSR in its current Ballston, VA location.

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